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FINAL REPORT

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RAIL ROUGHNESS STUDY OF THE HOLLOMAN HIGH SPEED ROCKET SLED TEST TRACK

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TEST TRACK DIVISION
6585TH TEST GROUP
HOLLOMAN AIR FORCE BASE, NEW MEXICO

1 SEPTEMBER 1981

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Data from a first order survey of the Holloman High Speed Rocket Sled Test Track was statistically analyzed to characterize the roughness of the rails. The rail roughness is a forcing function manifested as vibration in high speed sled tests conducted on the Track. Statistical methods in the space and frequency domain were developed and discussed and further data requirements were justified.

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FOREWORD

This report was prepared by the Test Track Division, Holloman Air Force Base, New Mexico, under System Development Plan entitled "Unified Sled Design Techniques."

The authors wish to express their appreciation to the many individuals who significantly contributed to completion of the final report, and in particular to Mr Bob Thede, Guidance Analysis Branch, for his timely preparation and adaptation of computer programs and accurate processing of the data. Special appreciation is also expressed to the Track Measurement Section that gathered the precise data through many hours of diligent surveying. Particular thanks are extended to Mrs Rosemary Phelps for typing the report.

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1. INTRODUCTION

1.1 Purpose

The purpose of this study was to define and determine the "roughness" of the Holloman High Speed Rocket Sled Test Track. Results of the study will be used to:

1.1.1 Provide forcing functions for Sledyne, a computer simulation program for structural analysis, and

1.1.2 Determine the effectiveness of rail grinding in reducing rail roughness, and hence reducing dynamic loads imparted to rocket sleds.

1.2 Background

The Holloman Test Track is a totally unique facility that offers a one-of-a-kind capability for testing aerospace equipment. The Holloman track is almost 10 miles long and has the smoothest and straightest rail surface in the free world. Each rail is continuously welded and under tension at temperatures less than 140°F. A sketch of the Holloman Test Track showing construction completion dates and track cross sections is shown in Figure 1.

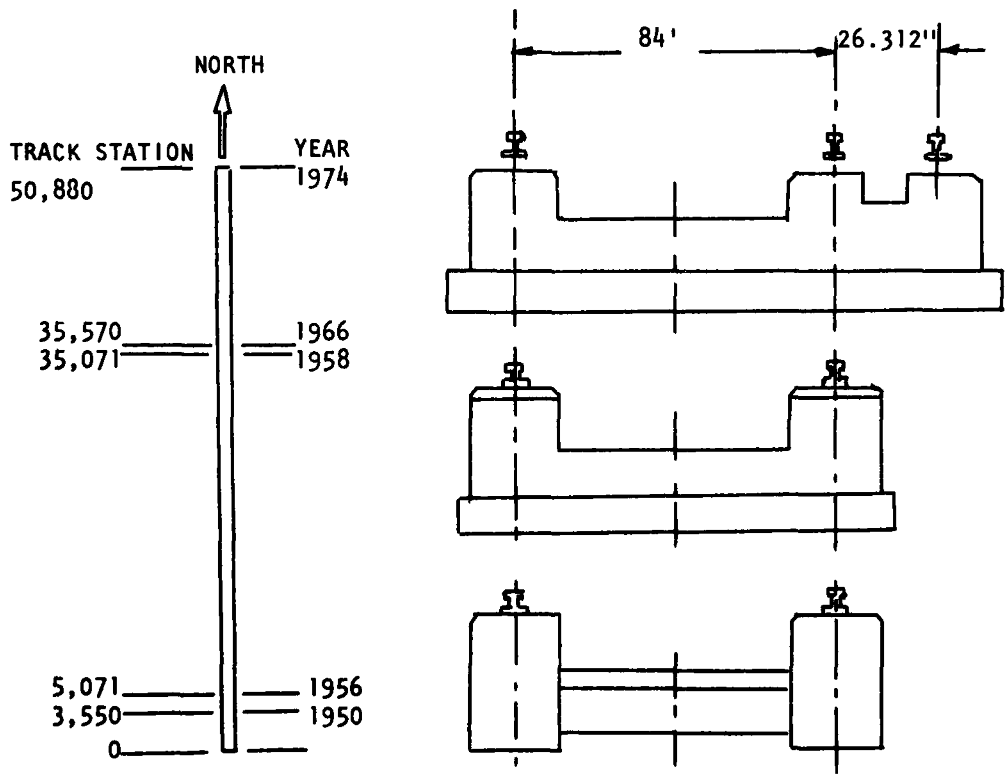


FIGURE 1. TRACK LAYOUT AND GIRDER CROSS SECTIONS

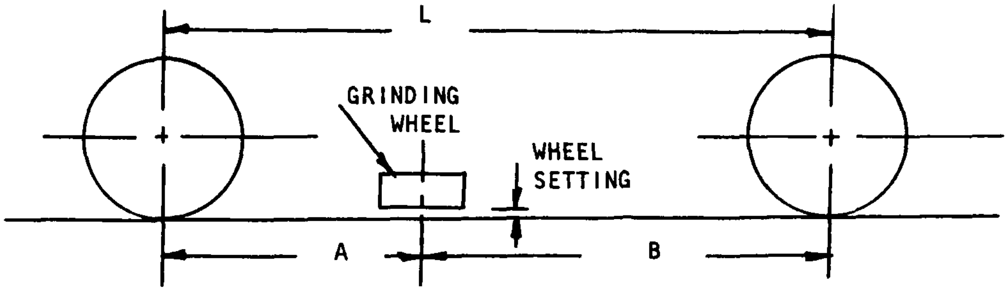
The original 3,550 foot facility, built in 1950, was extended to 5,071 feet in 1956 and is of a different girder cross-section from subsequent additions. In 1958 a major addition was completed which lengthened the facility to 35,071 feet. A short section was added in 1966 for a blast test program. The last extension was completed in 1974 and brought the total length to 50,880 feet; however, this last 15,310 feet was not fully operational until 1978 due to problems in a settlement area. As shown in the sketch, the original track was built on an 84-inch gage; the last 15,310 foot addition has a third rail 26.312 inches east of what was previously referred to as the east rail. This narrow gage capability allows for impact testing 3 foot diameter payloads in a Mach 4 velocity regime.

The purpose served by the Test Track is to provide a path which is as straight as is technically and economically feasible for a 10-mile outdoor facility; minor irregularities in the guiding surfaces can cause destructive dynamic forces and increase vibrations to unacceptable levels. Continuous surveys (and realignment) are conducted on the rails to insure rail alignment in both the vertical and lateral directions. Detailed procedures and tolerances are given in references 1 and 2. These references provide step-by-step descriptions of the procedures and in-depth appraisal on what the alignment and smoothness goals mean in actual application. For this study, the alignment goal is summarized as $\pm$ 0.005 inches to a fiducial (reference) line established by a U.S. Coast and Geodetic first order survey. This tolerance applies to the vertical and lateral direction for the west rail (master rail). The east rail and the third rail on the north 15,310 foot of track are aligned within $\pm$ 0.010 inches to the master rail by the means of fixtures.

1.3 Rail Grinding Technique

Separate from the alignment procedures, rail grinding is used to straighten the rails between the 52-inch space tie-downs. Grinding is accomplished after an initial rail bending procedure. As noted in Reference 2, "The entire process is, therefore, based on the premise that the points tied down by the alignment fixtures are located on a straight line, and that only the stretches between these fixtures should be affected by grinding." In actual practice, the grinding does have a smoothing effect over long distances as will be shown later in this study.

Two grinding machines have been developed over the past 25 years. The wheel bases and relative location of the grinding wheels are shown in the following sketch.



MACHINE	L (INCHES)	A (INCHES)	B (INCHES)
1	188	72.0	116.0
2	192	100.8	91.2

The principle of operation is defined as "profile averaging" method where the grinding machine is independent of external guideways and becomes self-aligning. Detail description of the evolution of these techniques are given in Reference 2. As previously described, the goal is to result in smooth rail surfaces that follow a straight line in the vertical and lateral planes.

1.4 Definition of Roughness

Before the study can progress, the definition of rail roughness must be determined and stated unambiguously. For purposes of this study, rail roughness was defined as the variations (or residuals) remaining after a best fit (least squares) straight line slope was removed from data surveyed at one foot intervals along the track. This rationale was justified by the fact that the slope would

provide only low frequency forcing functions to sleds, frequencies below the range of interest. The one foot interval was selected as a minimum interval which was economically feasible to obtain.

In this study residuals from various track stations are going to be compared as roughness. The validity of each set of residuals is dependent on the goodness-of-fit of each line. So, the coefficient of determination for each line was checked to insure it was different from zero. All were significantly different from zero. In addition, to compare residuals, the standard error of the estimate was utilized. This comparison is valid only if the coefficients of determination are not significantly different. Two of the 24 stations had coefficients of determination different from the rest. The two stations were at the north end, and each had a slope a magnitude smaller than the rest (and very nearly zero). Rigorously, the standard deviation rather than the standard error of the estimate (or conditional standard deviation) should be used. But for the sake of uniformity, the standard error of the estimate was used. In these two cases, since the slope was so small, there was little difference in the two parameters.

1.5 Sledyne

This rail roughness data will be used in the Sledyne computer program. Sledyne is a computer program used in sled design that takes the two rigid body modes of vibration and the first six (6) flexible modes of vibration in the pitch plane and, coupled with input parameters, calculates static G-forces at each finite mass point equivalent to the maximum dynamic response of the model. The six flexible modes of vibration are derived from another computer simulator, NASTRAN. NASTRAN uses an eigenvector/eigenvalue solution to a finite element model of the sled structures. The other input parameters are the stiffness of the supporting structure between the rail and the sled body, quasi-steady state forces such as lift, thrust, etc., velocity of the rocket sled and the non-linearity associated with the slipper gap. The velocity versus time data is used to modulate the rail roughness and results in a displacement versus time forcing function for the Sledyne simulation.

Sledyne was developed in 1974 and the only rail roughness data available was one 480 sample set taken along one 400 foot location on one rail in 1969. Data was taken every 10 inches at one point in the top center of the rail head. Additional discussion of this data will be provided later in the study.

Sledyne provides simulation only in the pitch plane and since only one line of rail roughness had been measured, the forcing function is started at a random point along the 400 ft sample and repeated in a continuous loop manner until the simulation is complete. The known length between front and aft slipper is used to insure that the aft slipper follows the front slipper in a physical sense. In the case of dual rail, each front slipper is started at different random points in the sample and repeated. The aft slippers longitudinal location is again specified.

Sledyne is obviously using a very small sample to derive a model of its forcing function. The original purpose of this study was to better characterize the track and toward that end the Sledyne forcing functions will be modified to include the results of this report.

1.6 Rail Grinding

A logical by-product of this report is to address a more basic question: Does required grinding result in significantly smoother rail surfaces? The two grinding machines were developed at a significant capital investment and the continued grinding is a constant drain on limited resources.

The data utilized in this study were obtained in early 1978. In March 1979 the status of rail grinding was as follows:

Track Station 0 to 35,570 ft

Top (1 & 2)	0.010"	
Sides (1 & 2)	0.025"	(one third ground to .010")
Bottom	None	

Track Station 35,570 to 50,880 (FY74 extension)

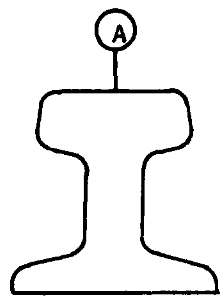
Top (1 & 2)	0.025"	(3) .010"
Sides	None	
Bottom	None	

As of June 1981, the only additional grinding that has been accomplished on the master rail is the top from track station 35,570 to 50,880 which has been ground to 0.010" and the east side of the master rail from 35,510 to 50,880 has been ground to 0.025". Note the 1978 measurements were taken on the west side of the master rail.

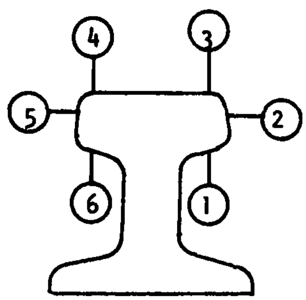
So the data from the south 35,000 feet can be compared with the north 15,000 feet to determine whether grinding has effected roughness. If the results of this study found no difference, a substantial savings could be realized.

1.7 Data Collection

In 1969 a first attempt was made to measure rail roughness. One set of data was measured for approximately 400 feet along the top of the west rail. Measurements were taken every 10 inches. This effort provided a 486 continuous sample; however, the measurement was taken only at one point of the rail cross-section, point A in the sketch.



This initial effort was less than desirable, since the monorail rocket sled rides on the following six (6) positions:



This observation can be verified by placing a monorail on the rail and positioning the sled in various conditions of roll. Dual rail, narrow gage sleds and outrigger rocket sleds ride on fewer surfaces since the roll movement is limited by the use of two rail heads.

In May 1978 a complete series of track roughness measurements were made much more extensive than the earlier 1969 set along one 400 foot section of rail. These new measurements were made in four phases. As shown in Table A, the plan was to take 25 sets of data every 2,000 feet along the track. Each set would contain 51 measurements of three roughness measurements at positions A, B and C in Figure 2. In actual practice rail side water trays were installed at track station 20,000, which obstructed any measurements at that station. Based on the earlier effort, measurements were made every one (1) foot in preference to 10 inches, since it had been demonstrated that the energy for periods of less than two (2) feet is small; i.e., two orders of magnitude smaller than the longer periods. A complete listing of this data is given in Appendix A.

The sampling philosophy was a compromise of varied and somewhat contradictory sampling requirements, survey techniques and economics. First, true sampling requires random samples which in this case would require n samples along the length of the track. However, survey techniques preclude accurate surveys over 250 to 300 feet for a single set. In addition, frequency domain analysis to meet the primary objective of the study required samples at regular, small intervals.

The sample size of 51 was derived by a trade-off between economics and confidence in derived statistics. In experiment design, the cost of data must be weighed against the probability of reaching incorrect conclusions. The two error types to be considered are the α or Type I error and the β or Type II. A Type I error is one in which a hypothesis that a sample statistic equal the population statistic is rejected when in fact they are equal. A Type II error is one in which the hypothesis is accepted when in fact it is false.

For this test, the basic hypothesis is that the standard deviation of the residuals of the samples is less than or equal to the standard deviation of the population residual. Or stated concisely;

$$H_o: \ s \leq \sigma$$

The alternative hypothesis is that s is greater than σ ;

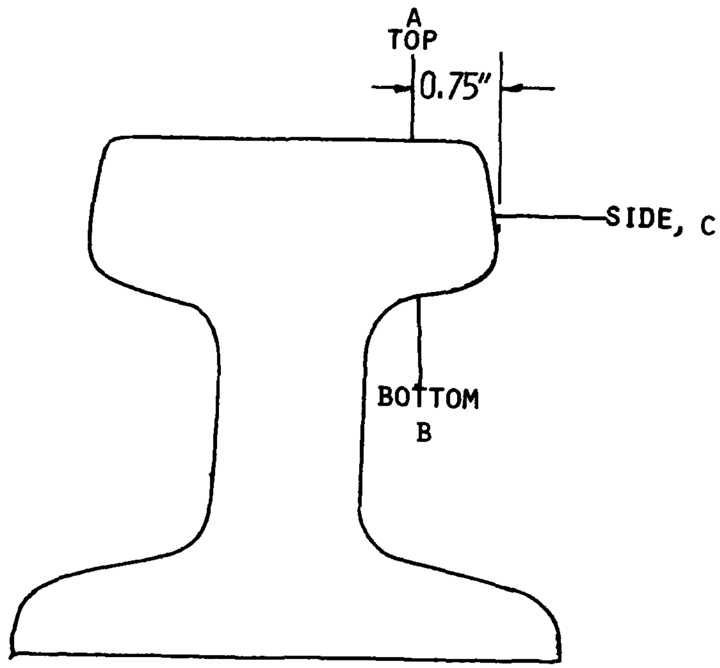
$$H_1: \ s > \sigma$$

TABLE A. PHASES FOR TRACK SURVEY OF RAIL ROUGHNESS.

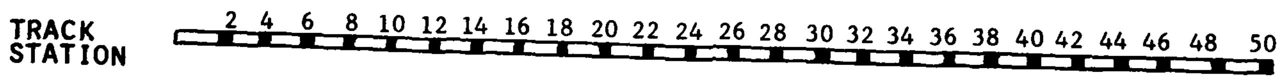
SAMPLE NO.	TRACK STATION	PHASE I	PHASE II	PHASE III	PHASE IV
1	2,000	51 pts			
2	4,000			51 pts	
3	6,000		51 pts		
4	8,000				51 pts
5	10,000	51 pts			
6	12,000			51 pts	
7	14,000		51 pts		
8	16,000				51 pts
9	18,000	51 pts			
10 *	20,000			51 pts	
11	22,000		51 pts		
12	24,000				51 pts
13	26,000	51 pts			
14	28,000			51 pts	
15	30,000		51 pts		
16	32,000				51 pts
17	34,000	51 pts			
18	36,000			51 pts	
19	38,000		51 pts		
20	40,000				51 pts
21	42,000	51 pts			
22	44,000			51 pts	
23	46,000		51 pts		
24	48,000				51 pts
25	50,000	51 pts			

*Was not accomplished due to interference with rail side water braking trays.

MAY 1978 SURVEY



WEST (MASTER) RAIL LOOKING SOUTH



51 SAMPLES AT EACH LOCATION

FIGURE 2. RAIL CROSS-SECTION MEASUREMENT LOCATIONS

For this sample size, 51, and referring to a single tailed (upper tail) χ^2 operating characteristics curve for $\alpha = .05$ and $\beta = .05$, $s \leq 1.5\sigma$ (See Pg 302, Reference 3). A sample size of 100 would only decrease the uncertainty such that $s \leq 1.3\ \sigma$. Thus, a sample size of 51 appears to be a good compromise between confidence and economics for analysis in the amplitude domain. Analysis in the frequency domain will be discussed later.

The 24 sets of 51 measurements were made at three (3) points in the cross-section view of the west rail. See Figure 2. A total of 3,672 measurements were made of the possible 152,310 point population starting at even track stations. The track is orientated in the north-south direction and the furthest west rail was selected for the measurements. This rail is designated as the master rail and is aligned in the vertical and horizontal planes to the fudicial line which is marked on bench marks located every 99 foot 8 inches directly west of the west rail on the concrete girder. The fudicial line was established by the U.S. Coast and Geodetic Survey to a first order accuracy. These basic survey points are described in considerable detail in references 1 and 2.

The first step in the survey was to scribe marks on the rail at each of the predescribed 153 (A, B and C at 51 stations) measurement points. A paragon level was then attached to the east rail (7 foot to the east of the west rail) at a point midway from the first measurement and the 51st measurement. The distance from the horizontal plane defined by horizontal sweep plane of the paragon level to point A was measured at each of the 51 locations. After the 51st measurement the level instrument was returned to the first measurement and was required to repeat the original measurement to 0.005 inches. The same fixture used to locate point A was used to locate the point where point C was measured.

The next measurement was the side roughness. A K&E Gig Transit was referenced to each bench mark and sighted to the next bench mark 99 feet 8 inches down track. Using this reference, the distance B, Figure 2, was measured with a modified micrometer. A micrometer was modified so it would fit only in a predescribed position on the rail with respect to point A. In this manner, the cap thickness was measured to an accuracy of 0.001 inches. The rail bottom roughness is then the addition of measurement A and measurement B.

2. DATA PROCESSING (AMPLITUDE DOMAIN)

As mentioned above the first step in data processing was to calculate the slope and intercept of a best fit straight line for each set of data. (Throughout this report a set of data is 51 continuous samples from the rail top, bottom or side.) The slope and intercept were then removed from the data, leaving only the residuals which have been defined as rail roughness. Note that the bottom was not assumed to be parallel to the top, i.e., a slope was calculated for each.

Also calculated during this regression analysis was the standard error of the estimate or the conditional standard error. Mathematically, the standard error of the estimate is rigorously more correct to discuss after a regression line has been extracted. Practically the standard error of the estimate is nearly identical to the standard error of the residuals and the terms will be used interchangeably. Appendix A shows the collected raw data and the data after the regression line has been removed. A summary of the data is given in Table B.

Implicit in using the standard error is the assumption that the residuals would be normally distributed. In fact, the normality assumption significantly simplifies all statistical techniques used in the analysis, and this assumption is valid from two aspects: (1) The residuals after a least squares fit should be normal, and (2) the central limit theorem states that a large sample should be normally distributed about its average, even if the population is not normally distributed.

Running the risk of asking a question and receiving an unsatisfactory answer, 47 of the 72 sample populations were compared with a normal distribution using a χ^2 goodness-of-fit test. Of the 47, 6 failed to pass. The six were retested using a Yates correction for lack of continuity. None of the six passed with the Yates correction. As a final attempt, moments of the residuals were calculated and the skewness and kurtosis were calculated. One of the six was found to be normal. No explanation could be found for the contradiction, but calculation of moments is a more accurate test.

The five sets remaining were examined to determine why they were not normally distributed. Each set appeared to have several outliers; i.e., points that would be several standard errors from the mean of the data. To rigorously use those data, a Beta distribution would be required. Due to the significantly greater workload in using the Beta distribution, the five sets were assumed to be normal. If many more sets were found to be non-normal, the entire evaluation procedure would have to be changed.

TABLE B. SUMMARY OF SLOPES AND STANDARD ERROR OF ESTIMATE VS TRACK STATION.

TRACK STATION	TOP OF RAIL $MX10^{-3}$	$S_{Y/X}$	BOTTOM OF RAIL $MX10^{-3}$	$S_{Y/X}$	SIDE OF RAIL $MX10^{-3}$	$S_{Y/X}$
2,000	-12.30	8.88	-12.36	15.70	-.02	11.04
4,000	-11.63	11.47	-11.51	14.20	-.37	11.71
6,000	-13.75	10.47	-13.91	15.50	+.33	12.13
8,000	-21.29	9.95	-21.32	12.30	+.67	14.89
10,000	-18.00	12.21	-17.94	13.20	+.25	14.51
12,000	-18.32	17.36	-18.34	18.00	+.36	12.77
14,000	-21.73	9.03	-21.80	13.70	+.16	10.48
16,000	-18.10	9.67	-18.26	14.90	-.37	13.66
18,000	-15.66	9.40	-15.80	23.50	+.50	13.00
20,000	WATER TRAYS					
22,000	-10.73	14.21	-10.61	21.14	-.39	9.72
24,000	- 7.48	11.98	- 6.61	14.50	-1.27	9.68
26,000	- 6.17	12.09	- 6.09	16.30	+1.79	20.30
28,000	- 8.82	8.98	- 8.75	13.10	+.53	7.47
30,000	- 8.82	11.46	- 8.43	25.40	+.62	9.75
32,000	- 5.07	7.15	- 5.00	15.30	-.49	9.24
34,000	- 6.00	20.95	- 6.12	20.80	-.80	18.51
36,000	- 9.67	14.67	- 9.66	14.90	+1.22	16.62
38,000	- 9.81	12.34	- 9.06	17.11	+.08	17.97
40,000	-15.65	15.41	-15.30	17.60	+1.31	17.43
42,000	-10.65	15.80	- 9.66	29.000	+.34	20.70
44,000	-10.11	9.01	-10.10	10.00	+.16	12.05
46,000	- .86	23.87	- .83	26.00	+.29	26.61
48,000	- 1.81	16.91	- 1.83	16.80	-.27	31.26
50,000	+ .59	18.38	+ .63	19.30	-.04	14.99

M - Slope Removed (in/foot)

$S_{Y/X}$ - Standard Error of Estimate (thousandths of an inch)

3. CLASSIFICATION OF RAIL ROUGHNESS

Given the established or assumed normality of the data, a comparison can be made of rail roughness in several different groupings. First, each type of measurement, i.e., top, bottom, and side of rail, will be studied as a function of track station or distance down track. The purpose of these comparisons is to identify if any given location has irregularities significantly different from any other given location. This approach will permit an evaluation of rail grinding effectiveness in providing a significant smoothing of the rail surfaces. Second, a comparison will be made between the types of measurements, i.e., top compared to the bottom of the rail, and top compared to the side of the rail. This comparison again provides an evaluation of the effectiveness of rail grinding, since different degrees of grinding have been performed on the three different classification of surfaces. The top has received the most attention and the bottom surfaces have never been ground.

Figure 3 shows the Standard Error of Estimate (S_{yx}) for the top of the rail as a function of the 24 locations where the 51 sample size sets of data were measured. At the top of the figure is the standard error of three large ensembles which would separate the track into three spatial groups. The spatial groups are referred to as south (0-16K ft), central (18K - 34K) and north (36K - 50K).

A method was needed to statistically compare the groups of data. If the roughness changes significantly, the grouping of the data into classes of roughness would be beneficial in further discussion and recommendations. A procedure was found where any number of S_{yx}^2 values could be compared at once. This procedure is accomplished by means of the measure of L, sometimes referred to as the "criterion of likelihood " (reference 4). The equation is as follows:

$$L = \frac{\sqrt[n]{S_{yx1}^2 \times S_{yx2}^2 \ldots \times S_{yxk}^2}}{\frac{1}{n}(S_{yx1}^2 + S_{yx2}^2 \text{---} + S_{yxk}^2)}$$

where n = the number of samples under consideration. The numerator is the geometric mean of S_{yx}^2's, while the denominator is the arithmetic mean of the S_{yx}^2's. "If there are any differences between S_{yx}^2's, the value of L will be less than 1.0, approaching 0 as its lower limit. L = 0 represents a condition of maximum

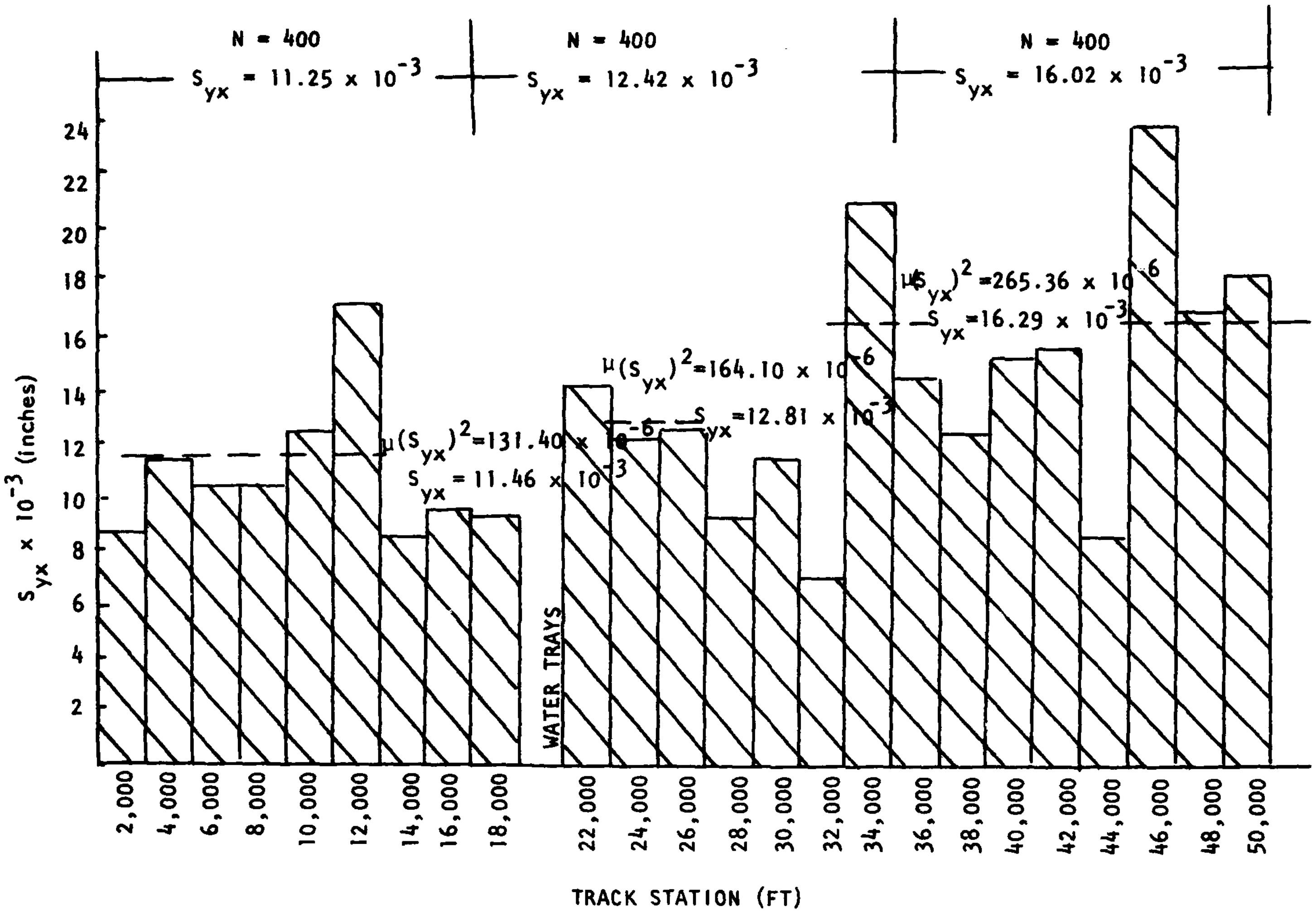


FIGURE 3. STANDARD ERROR OF ESTIMATE VS TRACK STATION
TOP OF RAIL

non-uniformity and is a theoretical limit which would not be approached in actual practice." The hypothesis to be tested is that the variances are from random samples of the same population in regard to S_{yx}^2. A table is given in Appendix N of Reference 4 which lists the values of L at the 0.05 and 0.01 points for various different degrees of freedom.

The 0.05 confidence level and 60 degrees of freedom values were used in this test. Use of the 0.05 confidence level and a higher degree-of-freedom, i.e., 60 instead of 51, forces a tighter grouping of the variances.

3.1 Top of Rail

Table C gives a listing of the standard error of estimate and variances in rank order for the top of the rail. The procedure calls for taking the first n samples and conducting the L test, if the n samples failed, the last sample was dropped from consideration and the test repeated for the reduced population. A sample calculation for Class A is as follows:

Let n = 6

$$L = \frac{\sqrt[6]{568.22 \times 443.52 \times 337.46 \times 302.41 \times 289.68 \times 246.49}}{\dfrac{568.22 + 443.52 + 337.46 + 302.41 + 289.68 + 246.49}{6}}$$

L = 0.9608

From Table for $N_i = 60$, $\alpha = 0.05$, n = 6

L = 0.969. Therefore, a set size of n = 6 fails the test. Now let n = 5.

$$L = \frac{\sqrt[5]{568.22 \times 443.52 \times 337.46 \times 302.41 \times 289.68}}{\dfrac{568.22 + 443.52 + 337.46 + 302.41 + 289.68}{5}}$$

L = .9667.

From Table for $N_i = 60$, $\alpha = 0.05$, n = 5, L = 0.968. Therefore, a set size of n = 5 passed the test. The bottom of the class will be assumed to be $S_{yx} = 17.02 \times 10^{-3}$ inches, and the maximum $S_{yx} = 23.85 \times 10^{-3}$ inches. The top of the next class will be assumed to start immediately below the next higher class, i.e., $S_{yx} = 17.01 \times 10^{-3}$ inches is assumed the top of Class B. Following this procedure the range of the standard error of estimate, S_{yx}, for each class is as follows.

TABLE C. TOP OF RAIL IN RANK ORDER.

TRACK STATION	$S_{yx} \times 10^{-3}$	$S_{yx}^2 \times 10^{-6}$	ROUGHNESS CLASS
46,000*	23.85	560.22	
34,000	21.06	443.52	
50,000*	18.37	337.46	A
12,000	17.39	302.41	
48,000*	17.02	289.68	
42,000*	15.70	246.48	
40,000*	15.31	234.40	
36,000*	14.77	218.15	
22,000	14.32	205.06	B
10,000	12.59	158.51	
26,000	12.55	157.50	
38,000*	12.36	152.77	
24,000	12.21	149.08	
30,000	11.63	135.26	
4,000	11.51	132.48	
8,000	10.44	108.99	
6,000	10.41	108.37	
16,000	9.68	93.70	C
18,000	9.35	87.42	
28,000	9.29	86.30	
44,000	8.76	76.74	
2,000	8.73	76.21	
14,000	8.40	70.56	D
32,000	7.03	49.42	

*North 15,000 Foot of Track.

	CLASS			
	A	B	C	D
S_{yx} (10^{-3} inches)	17.02 to 23.58	12.21 to 17.01	8.73 to 12.20	7.03 to 8.72
No. of Sets/Class	5	8	9	2

3.2 Bottom of Rail

The same analysis process was followed for the bottom of the rail as was conducted for the top of the rail. Figure 4 shows a bar graph of the Standard Error of Estimate (S_{yx}) for the 24 subsets of data as a function of track station. Again, for future analysis of power spectral density the data was also grouped into three sets of data for track stations 2,000 to 16,000, track stations 18,000 to 34,000, and 36,000 to 50,000, i.e., N = 408 per set. The criterion of likelihood can be used to establish if the mean, μ , of these three variances are of the same population as follows:

$$L = \frac{\sqrt[3]{218.45 \times 371.20 \times 387.03}}{\frac{218.45 + 371.20 + 387.03}{3}} = 0.968$$

From Appendix N, Reference 4, the value for L at $N_i = 60$, $n = 3$, and $\alpha = 0.05$ is 0.967; consequently, these three can be considered from the same population. These results were verified by conducting a one way Analysis of Variance on the three sets of standard errors.

Bottom of the rail data is given in Table D in rank order. The criterion of likelihood, L, was calculated to establish which variances were of the same class in a statistical sense. Results are as follows.

	CLASS		
	A	B	C
S_{yx} (10^{-3} inches	20.80 to 29.00	13.70 to 20.79	10.00 to 13.69
No. of Subsets/ Class	6	14	4

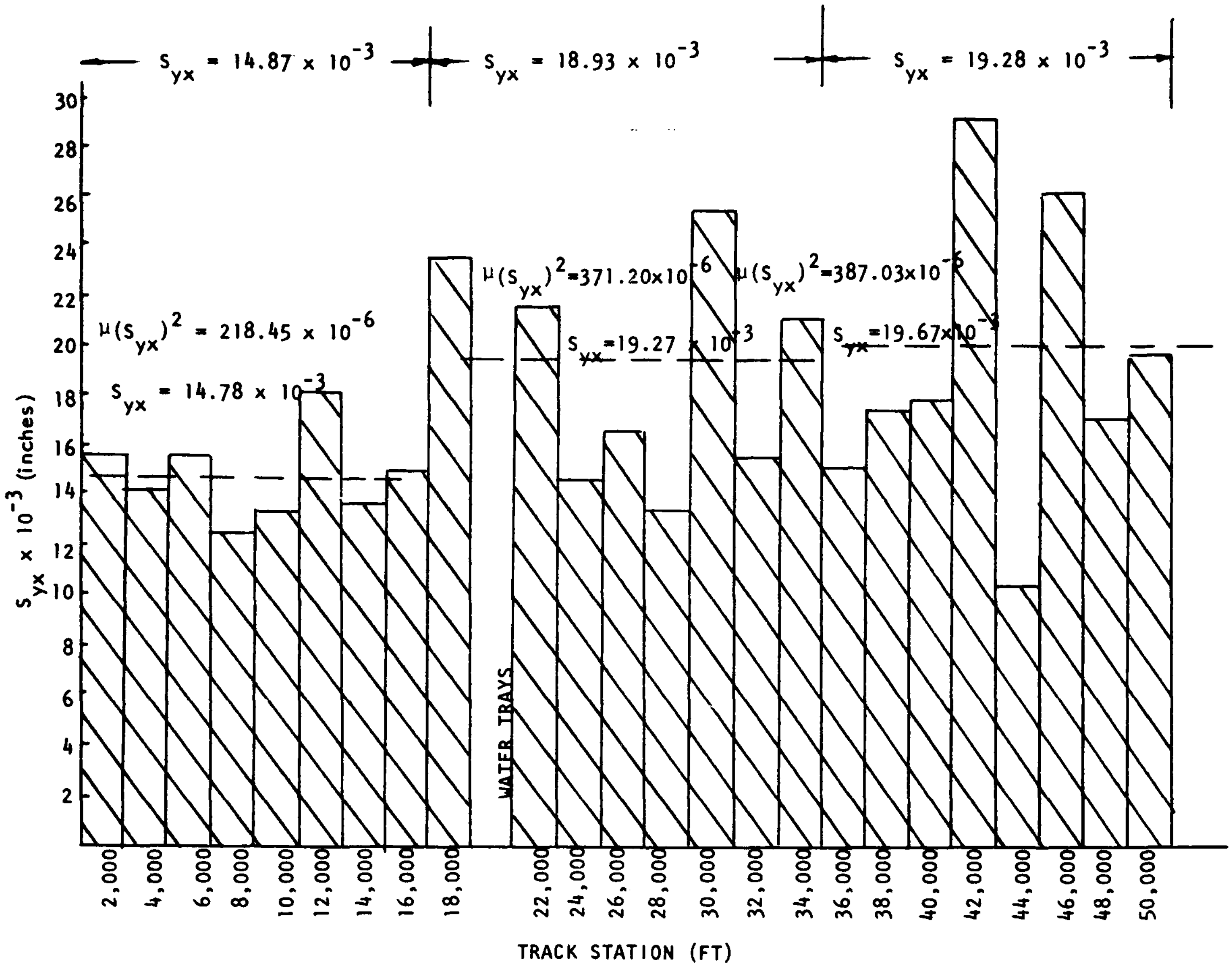


FIGURE 4. STANDARD ERROR OF ESTIMATE VS TRACK STATION
BOTTOM OF RAIL

TABLE D. BOTTOM OF RAIL IN RANK ORDER

TRACK STATION	$S_{yx} \times 10^{-3}$	$S_{yx}^2 \times 10^{-3}$	ROUGHNESS CLASS
42,000*	29.0	841.00	
46,000*	26.00	676.00	
30,000	25.40	645.16	A
18,000	23.50	552.25	
22,000	21.14	457.96	
34,000	20.80	453.64	
50,000*	19.30	372.49	
12,000	18.00	324.00	
40,000*	17.60	309.76	
38,000*	17.11	292.75	
48,000*	16.80	282.24	
26,000	16.30	265.69	
2,000	15.70	246.49	
6,000	15.50	240.25	B
32,000	15.30	234.09	
36,000*	14.90	222.01	
16,000	14.90	222.01	
24,000	14.50	210.25	
4,000	14.20	201.64	
14,000	13.70	187.69	
10,000	13.20	174.24	
28,000	13.10	171.61	C
8,000	12.30	151.29	
44,000*	10.00	100.00	

*North 15,000 Foot of Track

By comparing the top of rail classes with bottom of rail classes, it is shown that the bottom of the rail is a significantly higher forcing function as shown in this table.

	CLASSES			
	A	B	C	D
Top of Rail S_{yx} (10^{-3} inches)	17.02 to 23.58	12.21 to 17.01	8.73 to 12.20	7.08 to 8.72
Bottom of Rail S_{yx} (10^{-3} inches)	20.80 to 29.00	13.70 to 20.79	10.00 to 13.79	Not Req'd

3.3 Side of Rail

This analysis approach was repeated for the third time for the side of the rail. Figure 5 shows a bar graph of the Standard Error of Estimate (S_{yx}) for the 24 subsets of data as a function of track station. At the top of this figure, the S_{yx} and S_{yx}^2 values are listed for the larger sets of data where eight subsets were added to provide a sample size of N = 408. A comparison of L values for the three sets shows that the two sets from the south 35,000 feet of track are probably from the same population and the north 15,000 is of a different population. These results were also verified with a one-way Analysis of Variance test. Also, comparison of the variances for the three sets shows good comparison with the means, μ's, of the variances for the eight subsets which make up the larger samples, a further quality check of procedures.

Side of the rail data is given in Table E in rank order. The criterion of likelihood was calculated to divide the subset into statistical class if applicable. One different approach was necessarily from previous analyses. Due to the large difference between the second and third variance, the exact cut-off point had to be established. After several iterations, Class A extends down through S_{yx} = 23.20 x 10^{-3} inches. The same process was followed between Class B and C. Class B extends down through S_{yx} = 15.50 x 10^{-3} inches. The results can be summarized as follows:

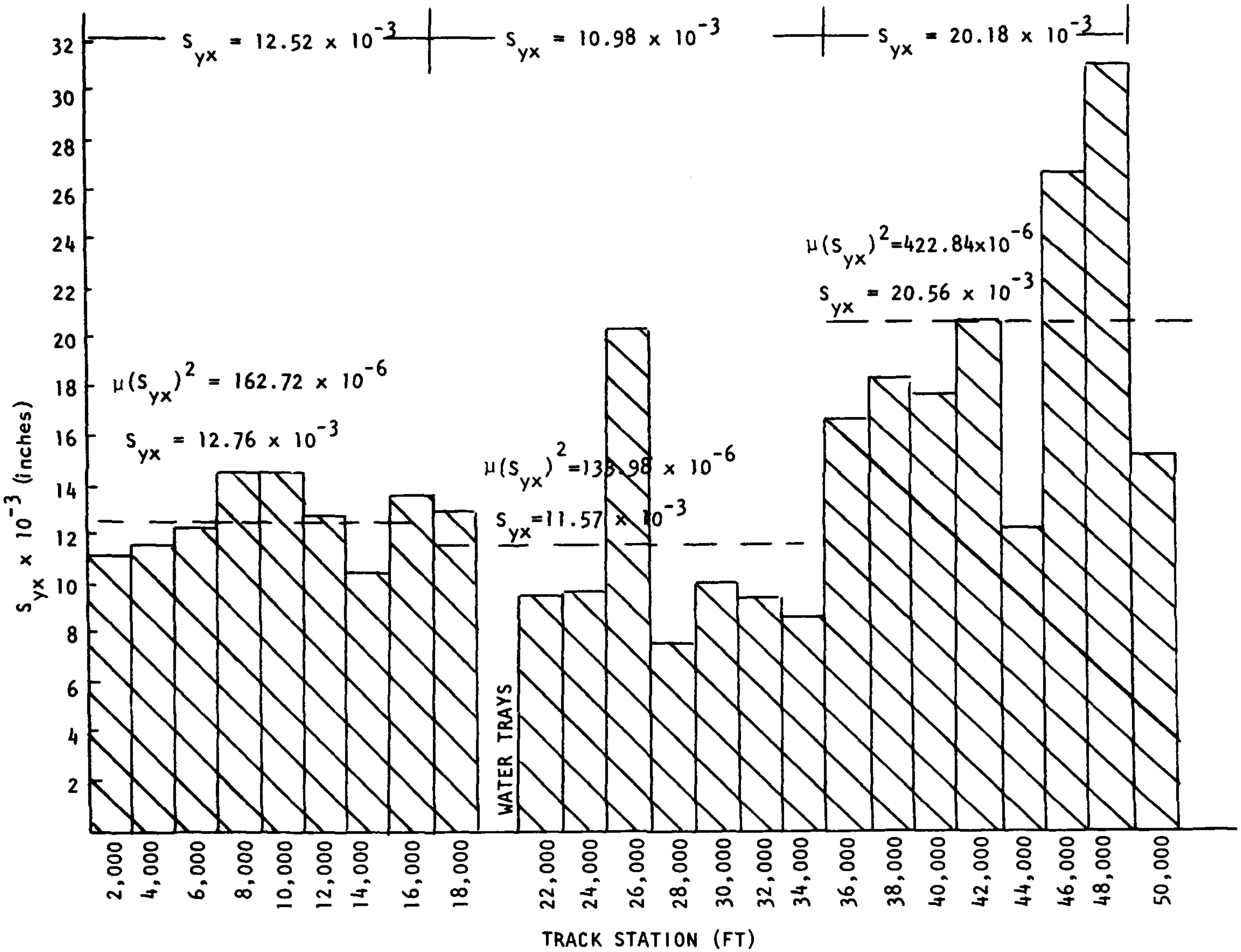


FIGURE 5. STANDARD ERROR OF ESTIMATE VS TRACK STATION SIDE OF RAIL

TABLE E. SIDE OF RAIL IN RANK ORDER

STATION	$S_{yx} \times 10^{-3}$	$S_{yx} \times 10^{-6}$	ROUGHNESS CLASS
48,000*	31.23	975.31	A
46,000*	26.58	706.50	
42,000*	20.69	428.08	B
26,000	20.26	410.47	
38,000*	18.03	325.08	
40,000*	17.40	302.76	
36,000*	16.68	278.22	
50,000*	14.99	224.70	C
8,000	14.91	222.31	
10,000	14.58	212.58	
16,000	13.74	188.79	
18,000	12.90	166.41	
12,000	12.79	163.58	
6,000	12.17	148.11	
44,000*	11.92	142.09	
4,000	11.63	135.26	
2,000	11.05	122.10	
14,000	10.44	108.99	D
30,000	9.81	96.24	
24,000	9.71	94.28	
22,000	9.69	93.90	
32,000	9.20	84.64	
34,000	8.52	72.59	
28,000	7.30	53.29	

*North 15,000 Foot of Track

	CLASS			
	A	B	C	D
S_{yx} (10^{-3} inches	23.20 to 31.23	15.50 to 23.19	11.05 to 15.49	7.30 to 11.04
No. of Subsets/Class	2	5	10	7

This difference could have come from rail grinding or from rail alignment. The south 35,000 feet have been surveyed and aligned to the million foot radius repeatedly over the years and should be straighter than the relatively new north end. The variations due to grinding and alignment cannot be separated, but overall the north end obviously has larger residuals than the south 35,000 feet. Note that seven out of the top eight subsets are from the north end measurements.

A comparison of the top of the rail with the side by classes is as follows:

	CLASSES			
	A	B	C	D
Top of Rail S_{yx} (10^{-3} inches)	17.02 to 23.58	12.21 to 17.01	8.73 to 12.20	7.03 to 8.72
Side of Rail S_{yx} (10^{-3} inches)	23.20 to 31.23	15.50 to 23.19	11.05 to 15.49	7.03 to 11.04

Based on this comparison the side of the rail is significantly rougher surface than the top.

4. DATA PROCESSING (FREQUENCY DOMAIN)

In order to better characterize the data and study the effectiveness of rail grinding, the data was analyzed in the frequency domain. As in the amplitude domain, only the residuals (after removal of the regression line) were considered.

For frequency domain analysis, the data were grouped into larger ensembles as previously shown - south (2,000 - 16,000 feet), center (18,000 - 34,000 feet), and north (36,000 - 50,000 feet). The grouping was done by simply zeroing the first and last element of each 51 sample set, then aggregating eight adjacent samples. The net result is a larger sample size to study, increasing the confidence of the estimates of the power spectral densities (PSDs). See Appendix B for plots of the ensembles.

This grouping results in three ensembles of 408 samples each. The ratio of the mean squared value of a sample data set PSD to the population PSD is found by a ratio of χ^2 values for a given confidence level of Type I and Type II errors, or

$$d^2 = \frac{\chi^2 n,\ \beta/2}{\chi^2 n,\ 1-\frac{\alpha}{2}}$$

For $n = 400, \alpha = .05$ and $\beta = .05$, $d^2 = 1.32$ or d (standard deviation) = 1.09. Consequently, the root mean - squared value of PSD's should be within a factor of 1.1 of the population PSD. (For same analysis in time domain - see Reference 5). This uncertainty was accepted since no systematic errors were expected and larger groupings would not meet test objectives. In effect, this grouping was similar to averaging in the amplitude domain. Since no data with a period longer than 50 foot could exist in the original data, none could exist in the 408 sample ensemble.

To compare the roughness of the three sets, the PSD of each ensemble for a given rail surface was compared with the PSD's of the other ensembles (same surface) pair-wise. The units of the PSD's may seem rather unique. The measurements were taken at one foot intervals so t orizontal or frequency axis dimension is in cycles per foot. The parameter being analyzed is inches of residual so the "power" axis has units of inches squared per cycle per foot. Note that the vertical axis is a linear scale of logarithm data, rather than the normal log scale of linear data. So the vertical axis scale are powers of 10, e.g., 10^{-4}, $10^{-3.5}$, etc.

4.1 Top of Rail

Figure 6 is a plot of the rail top for the south and center sections. Each curve is annotated to aid in resolution. There are two peaks on the graph which are relatively constant for these PSD's and all other PSD's analyzed. The peak at 0.0256 cycles/foot corresponds to the period of 39 feet. The other peak at 0.23 cycles/foot corresponds to a period of 52 inches.

The 39 foot component arises from the standard length of a rail section as it is delivered from the factory. Apparently a slight change in slope was introduced as the different 39 foot sections were welded together.

The 52 inch component corresponds to the spacing of the rail tie-down/alignment fixtures, i.e., the rail apparently sags (or humps) between tie downs. The rail grinding machines were designed to minimize variation of 52 inches and less, but the component is still prevalent.

One conclusion to be drawn from Figure 6 is that there is very little difference between the south and center sections for top of rail.

Figures 7 and 8 are similar plots comparing south and center sections to the north section. Recall that when the data was collected, the south and center sections had been ground to a machine setting of 0.010 inches and the north section to 0.025 inches for top of rail.

In order to quantify the difference, the PSD's were integrated to arrive at mean squared residuals. Some points of interest for the three sections are:

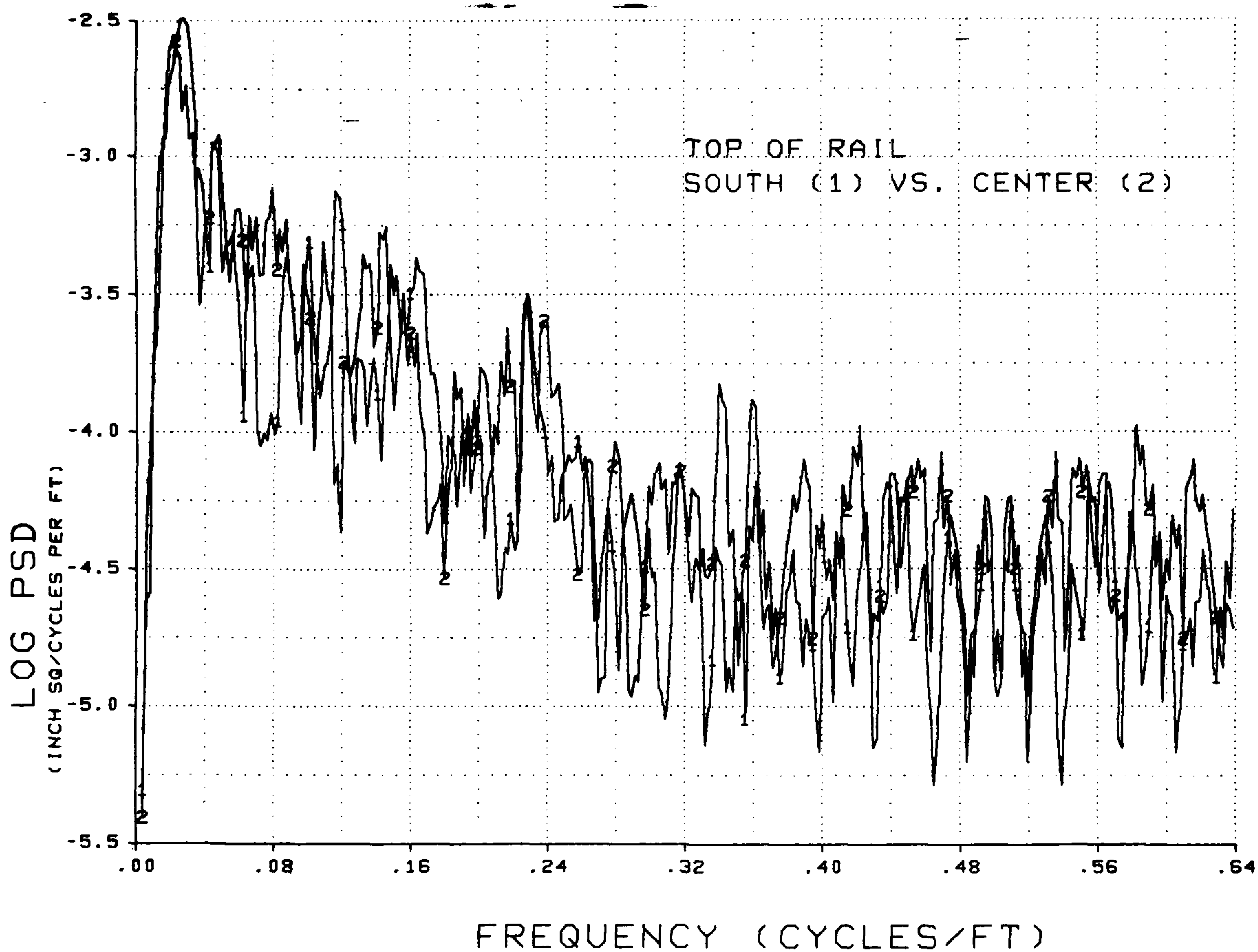
CUMULATIVE "POWER"
(Inches Squared)

f Cycles/Ft	L Ft	South	Center	North
.02539	39.38	.0131	.0136	.0064
.0332	30.10	.0188	.0243	.0139
.0645	15.50	.0283	.0351	.0498
.2342	4.27	.0459	.0557	.0936

There are several noteworthy points in these data.

4.1.1 As shown in the plots, the North end 39 foot component is about half the magnitude of the South 35,000 feet.

4.1.2 The amount of "power" at frequencies above 0.03 cycles/ft is twice as great for the North section as the South 35,000 feet.



TOP OF RAIL
SOUTH (1) VS. CENTER (2)
LOG PSD
(INCH SQ/CYCLES PER FT)
-2.5
-3.0
-3.5
-4.0
-4.5
-5.0
-5.5
.00
.08
.16
.24
.32
.40
.48
.56
.64
FREQUENCY (CYCLES/FT)

FIGURE 6

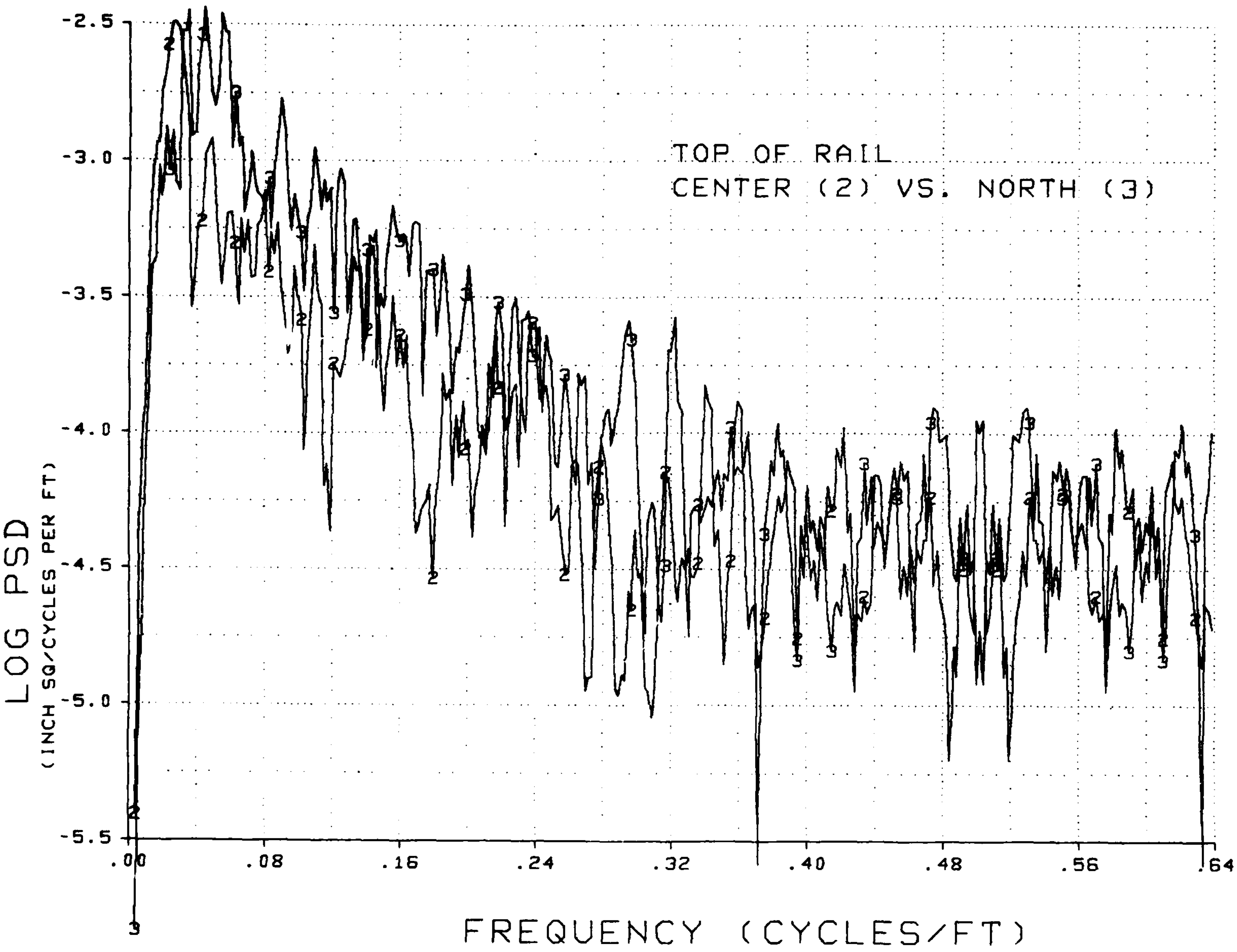

TOP OF RAIL
CENTER (2) VS. NORTH (3)
LOG PSD
(INCH SQ/CYCLES PER FT)
-2.5
-3.0
-3.5
-4.0
-4.5
-5.0
-5.5
.00
.08
.16
.24
.32
.40
.48
.56
.64
FREQUENCY (CYCLES/FT)

FIGURE 7

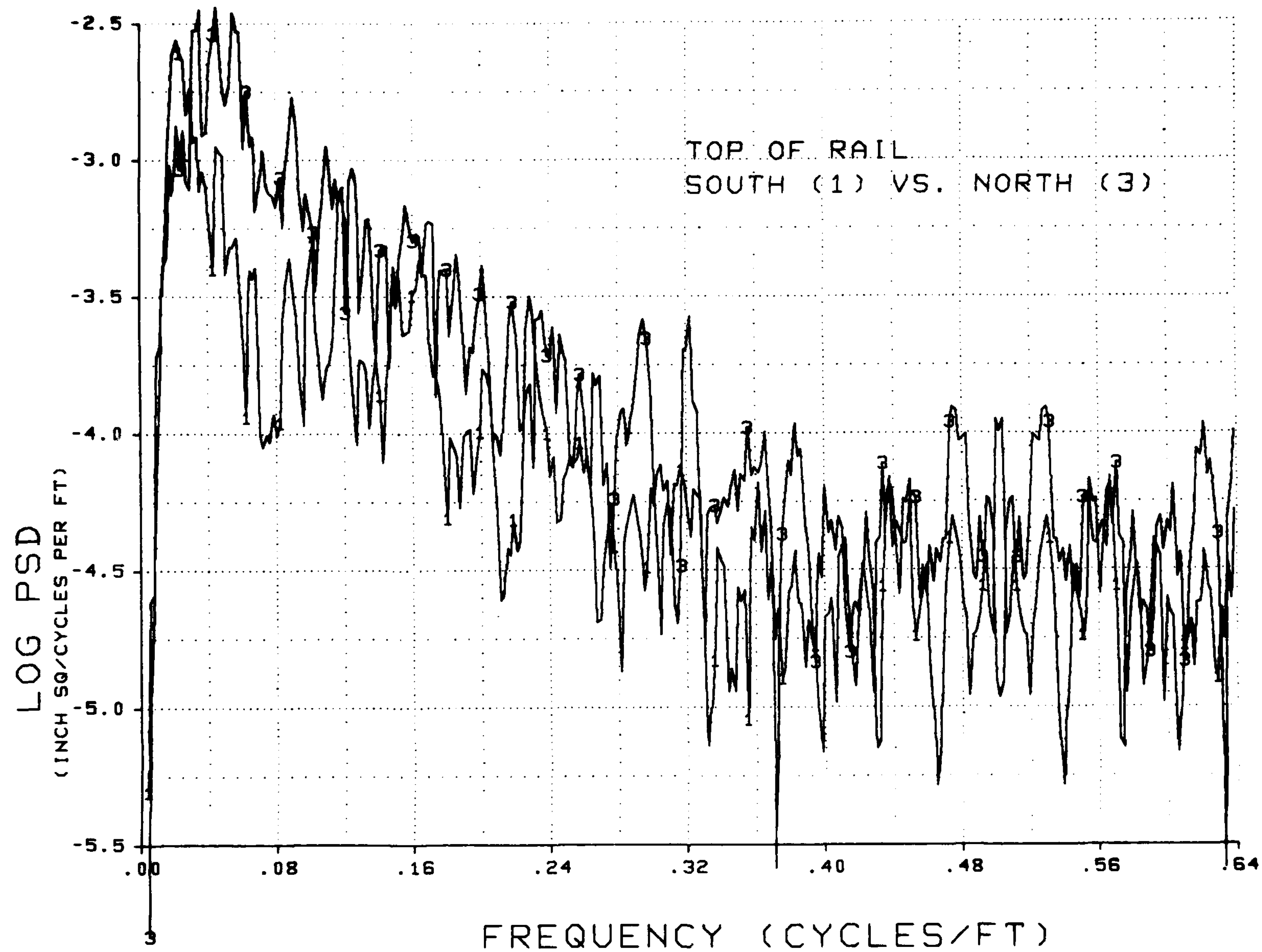

TOP OF RAIL
SOUTH (1) VS. NORTH (3)
LOG PSD
(INCH SQ/CYCLES PER FT)
-2.5
-3.0
-3.5
-4.0
-4.5
-5.0
-5.5
.00
.08
.16
.24
.32
.40
.48
.56
.64
FREQUENCY (CYCLES/FT)

FIGURE 8

4.1.3 Overall, the "power" in the North end is significantly higher than the remainder of the track.

4.1.4 Even though the rail grinders were designed to improve roughness at distances of 52 inches and less, there is a significantly lower amount of "power" in the South 35,000 feet in the 0.03 to 0.23 cycle/ft (30 - 4.3 feet) frequency band than in the North 15,000 feet of track.

4.2 Bottom of Rail

Plots 9, 10 and 11 are the PSD's for the rail bottom. The lower lips or bottom of the rail have received no grinding and the differences in the amplitude domain are not as obvious as the rail top. The same points of interest were checked as for the rail top as follows:

CUMULATIVE "POWER"
(Inches squared)

f Cycles/Ft	L Ft	South	Center	North
.02539	39.38	.0133	.0247	.0087
.0332	30.10	.0179	.0394	.0231
.0645	15.50	.0345	.0666	.0687
.2342	4.27	.0730	.1320	.1333

Noteworthy points are as follows:

4.2.1 Again the north end 39 foot component is significantly lower than the remainder of the track.

4.2.2 Overall the center and north sections are significantly rougher than the south 15,000 feet. One explanation could be is that the south end has had a significantly greater number of sled runs over the years. Wear from slipper loads tend to smooth the track surface the same as grinding. Also, there is a possibility that the lower surfaces were ground in the past and not documented.

4.3 Side of Rail

Plots 12, 13 and 14 are the PSD's for the side of the rail. The 39 foot component is again visible, especially in the north end. Also visible is the 52 inch period (.23 cycles/ft) in all plots.

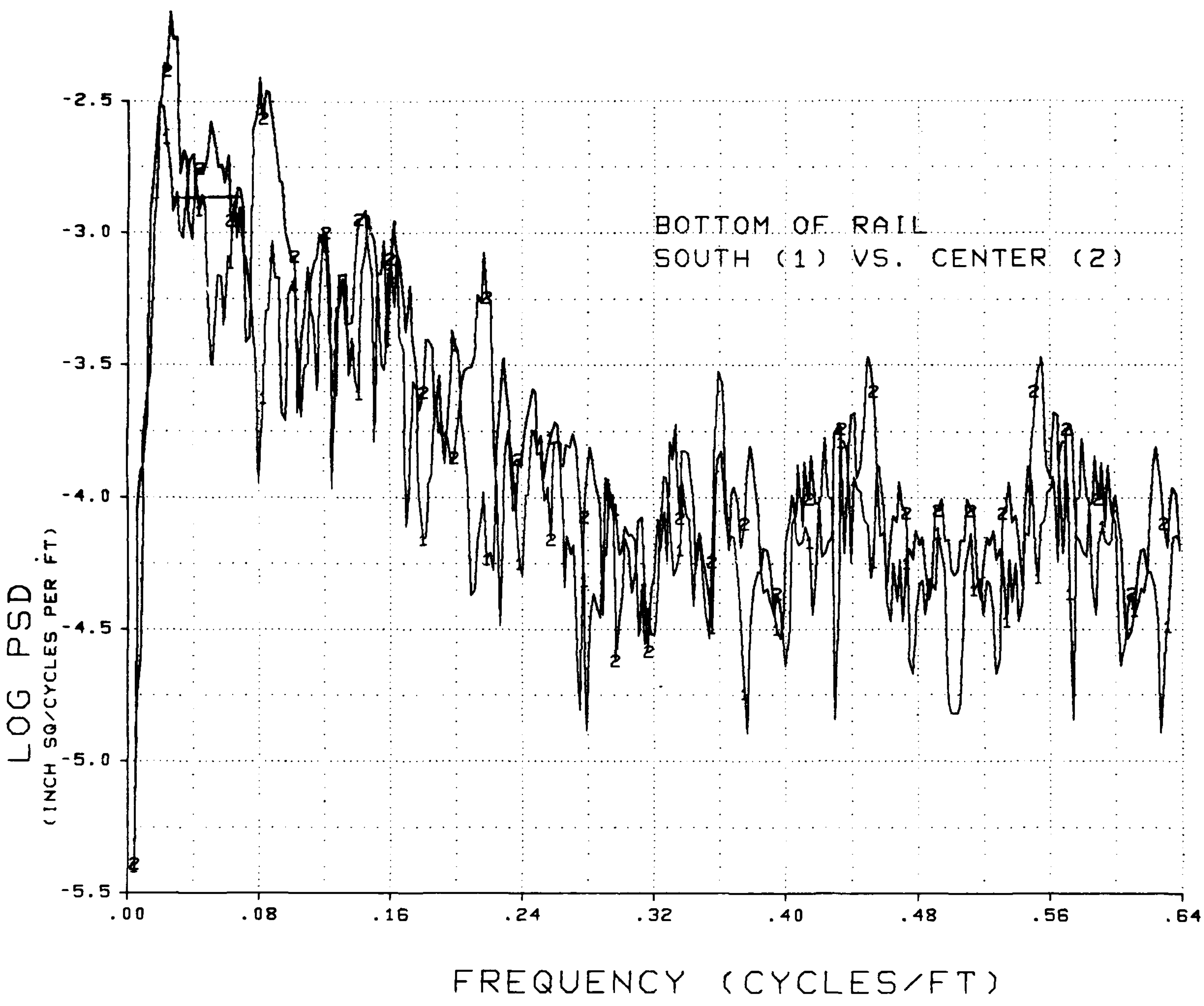
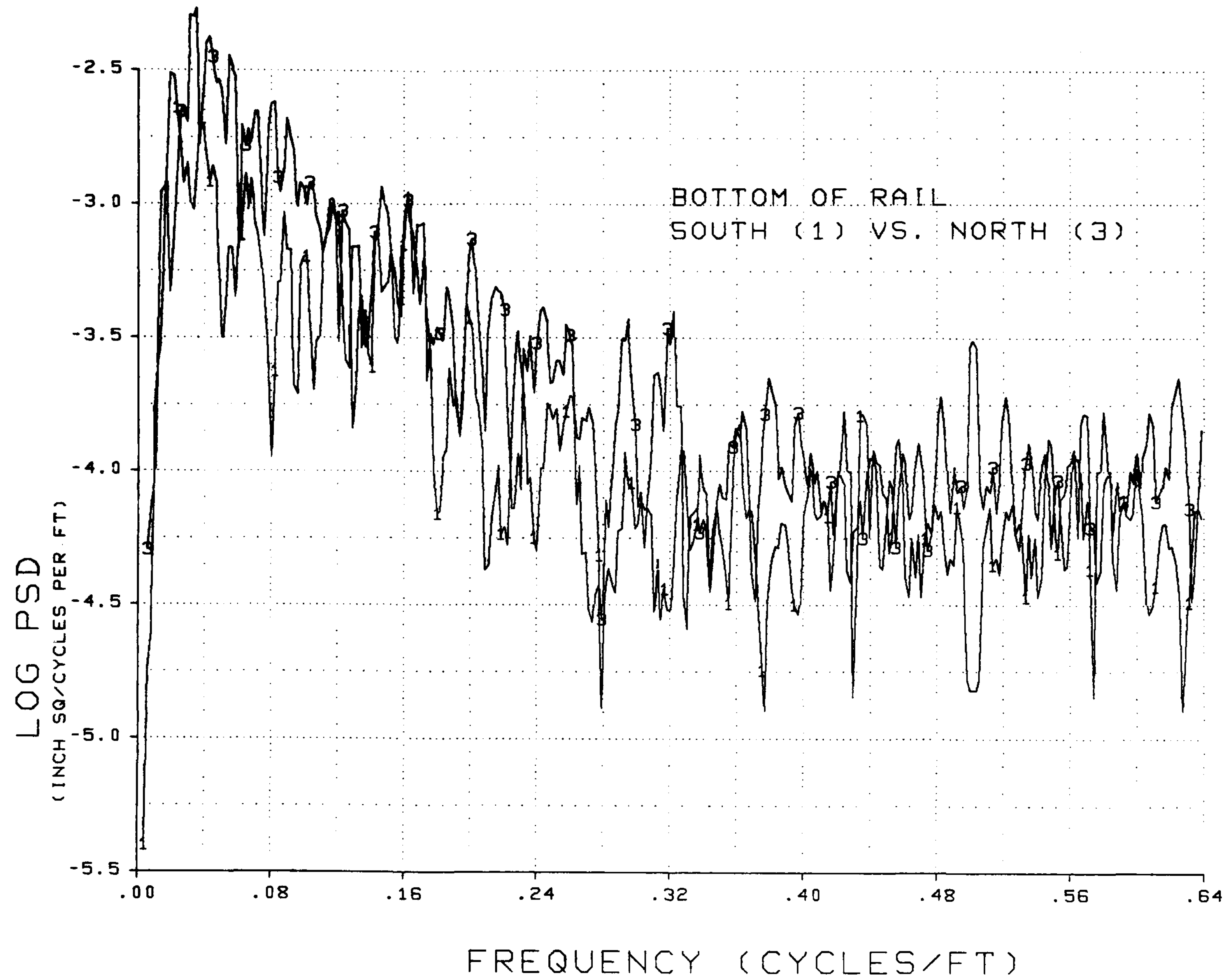

BOTTOM OF RAIL
SOUTH (1) VS. CENTER (2)
LOG PSD
(INCH SQ/CYCLES PER FT)
-2.5
-3.0
-3.5
-4.0
-4.5
-5.0
-5.5
.00
.08
.16
.24
.32
.40
.48
.56
.64
FREQUENCY (CYCLES/FT)

FIGURE 9



BOTTOM OF RAIL
SOUTH (1) VS. NORTH (3)
LOG PSD
(INCH SQ/CYCLES PER FT)
-2.5
-3.0
-3.5
-4.0
-4.5
-5.0
-5.5
.00
.08
.16
.24
.32
.40
.48
.56
.64
FREQUENCY (CYCLES/FT)

FIGURE 10

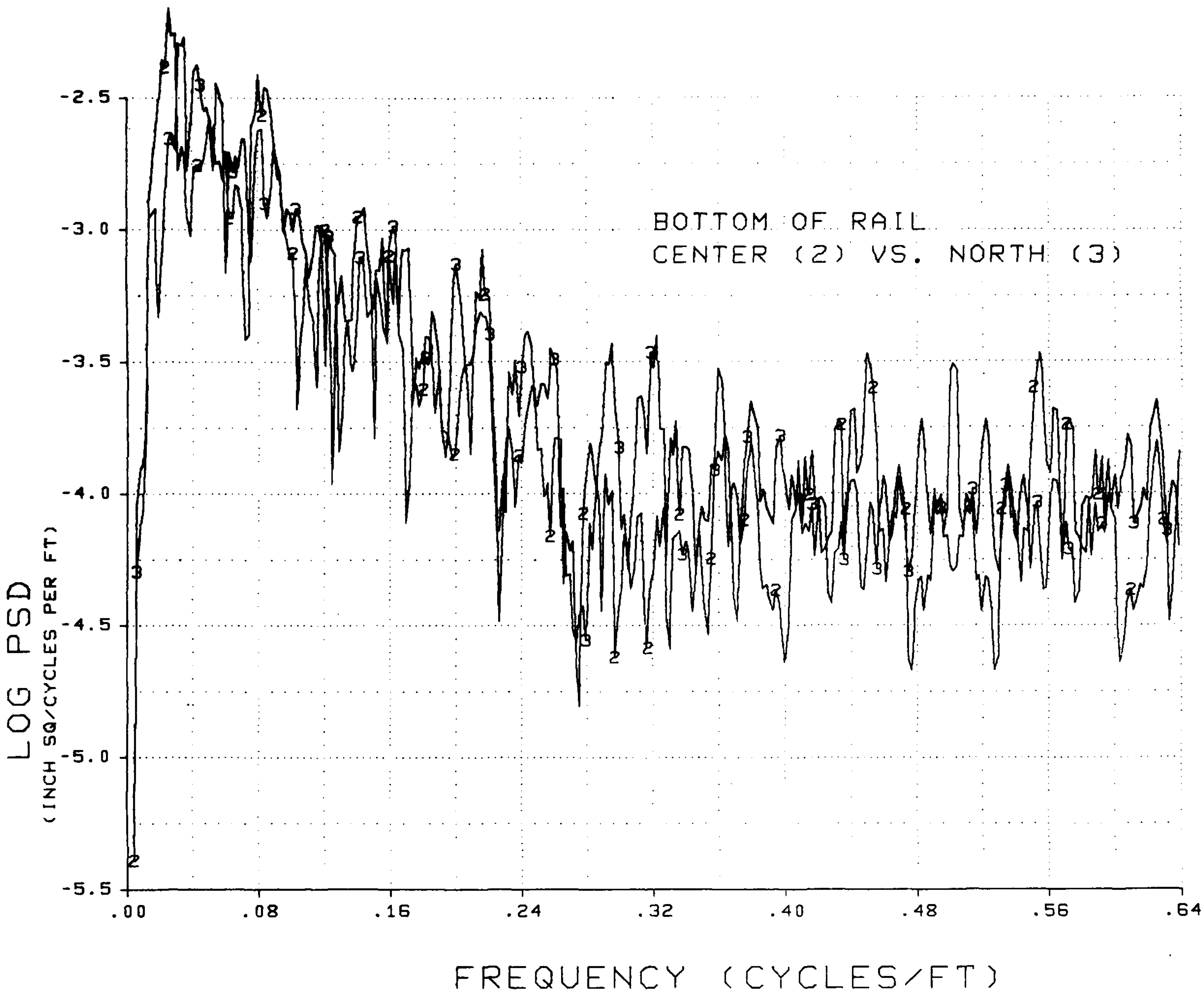
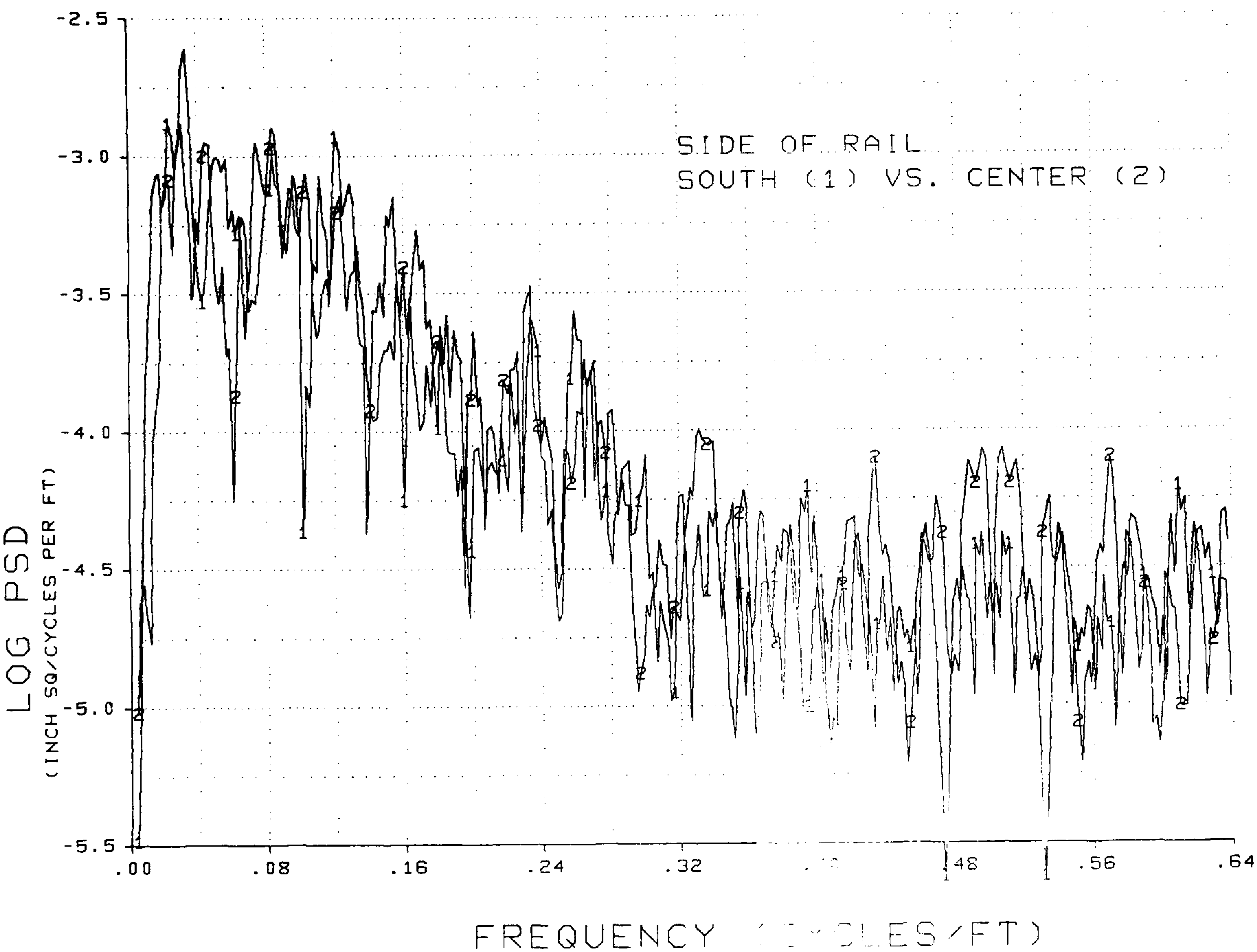
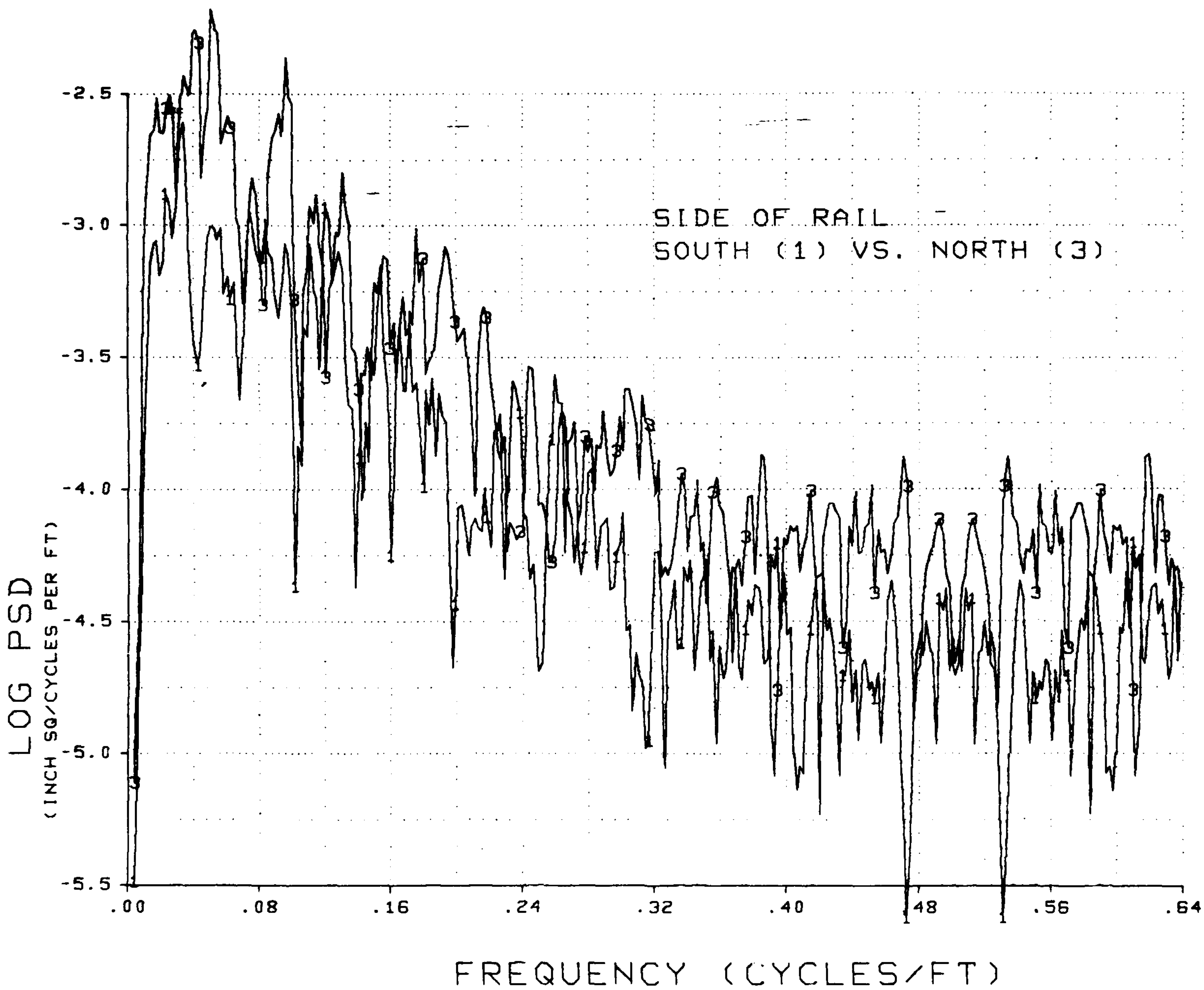

BOTTOM OF RAIL
CENTER (2) VS. NORTH (3)
LOG PSD
(INCH SQ/CYCLES PER FT)
-2.5
-3.0
-3.5
-4.0
-4.5
-5.0
-5.5
.00
.08
.16
.24
.32
.40
.48
.56
.64
FREQUENCY (CYCLES/FT)

FIGURE 11


SIDE OF RAIL
SOUTH (1) VS. CENTER (2)
LOG PSD
(INCH SQ/CYCLES PER FT)
-2.5
-3.0
-3.5
-4.0
-4.5
-5.0
-5.5
.00
.08
.16
.24
.32
.48
.56
.64
FREQUENCY
FIGURE 12


SIDE OF RAIL -
SOUTH (1) VS. NORTH (3)
LOG PSD
(INCH SQ/CYCLES PER FT)
-2.5
-3.0
-3.5
-4.0
-4.5
-5.0
-5.5
.00
.08
.16
.24
.32
.40
.48
.56
.64
FREQUENCY (CYCLES/FT)
FIGURE 13

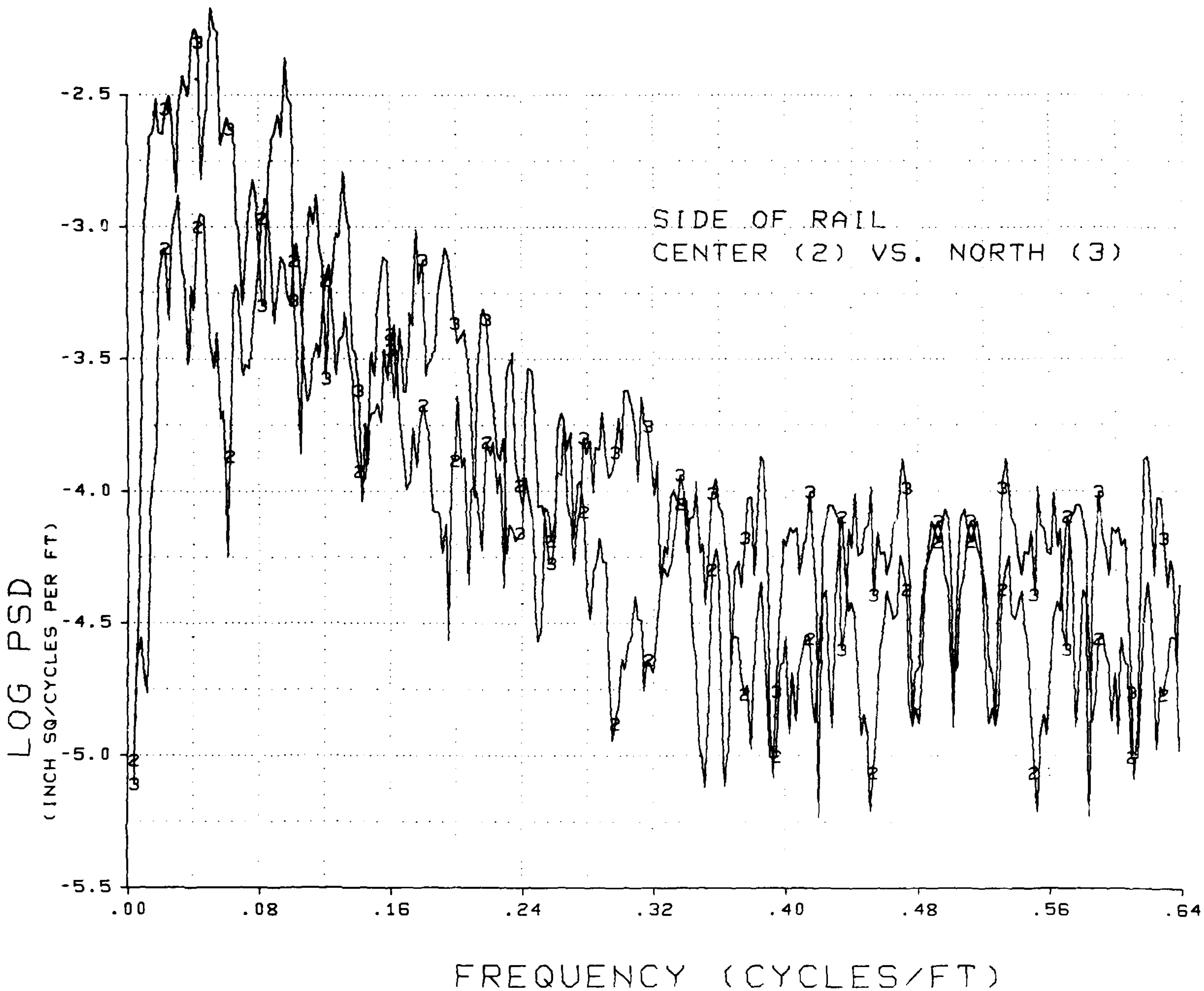

SIDE OF RAIL
CENTER (2) VS. NORTH (3)
LOG PSD
(INCH SQ/CYCLES PER FT)
-2.5
-3.0
-3.5
-4.0
-4.5
-5.0
-5.5
.00
.08
.16
.24
.32
.40
.48
.56
.64
FREQUENCY (CYCLES/FT)

FIGURE 14

A check of the integrated "power" is as follows:

f Cycles/Ft	L Ft	South	Center	North
.02539	39.38	.0068	.0032	.0203
.0332	30.10	.0134	.0072	.0306
.0645	15.50	.0251	.0152	.0894
.2342	4.27	.0572	.0426	.1535

The following comments are offered for these comparisons:

4.3.1 A reversal in trend is noted for the 39 foot period. In the case of the side the north is significantly rougher than the remaining 35,000 feet of track. Evidently the fabrication techniques that assured straight welded joints in the vertical direction was not carried through to the lateral or cross track direction.

4.3.2 Overall, the rail is significantly rougher in the north 15,000 feet of track where no grinding had been accomplished. Note the South 35,000 feet of track sides of rail had been ground to 0.025 inches.

4.4 In paragraph 4 it was pointed out that no data with a period of greater than 50 feet could exist in the original data. To appreciate the full ramifications of this statement, consider the data from a structural dynamics perspective. As pointed out in reference 5, the acceptable level of Type I and Type II errors must be determined while considering the costs of measurements. If measurements are relatively cheap, then the experiment can be set with high levels of confidence and power (e.g., α = .01, β = .01). In the case of track surveys, measurements cannot be considered cheap; therefore, lower confidence and power levels were investigated.

Three different combinations were considered – $\alpha = \beta = .01$; $\alpha = .01$ and $\beta = .05$ and $\alpha = \beta = .05$. The ratio d as defined earlier in this paragraph was calculated for n = 1000, 400, 280, 200, 100 and 50 for each of the three combinations. These results are presented graphically in plot 15 where d is plotted versus n, the number of samples. The top curve is for $\alpha = \beta = .01$ and the bottom is $\alpha = \beta = .05$. An observation is that going vertically up on the chart (holding n constant), d as a function of α & β varies greatly for small samples (n = 50) but varies little for large samples (n = 1000). Using the same criteria as found in reference 5 that d = 1.2, 280 samples would be required at $\alpha = \beta = .05$.

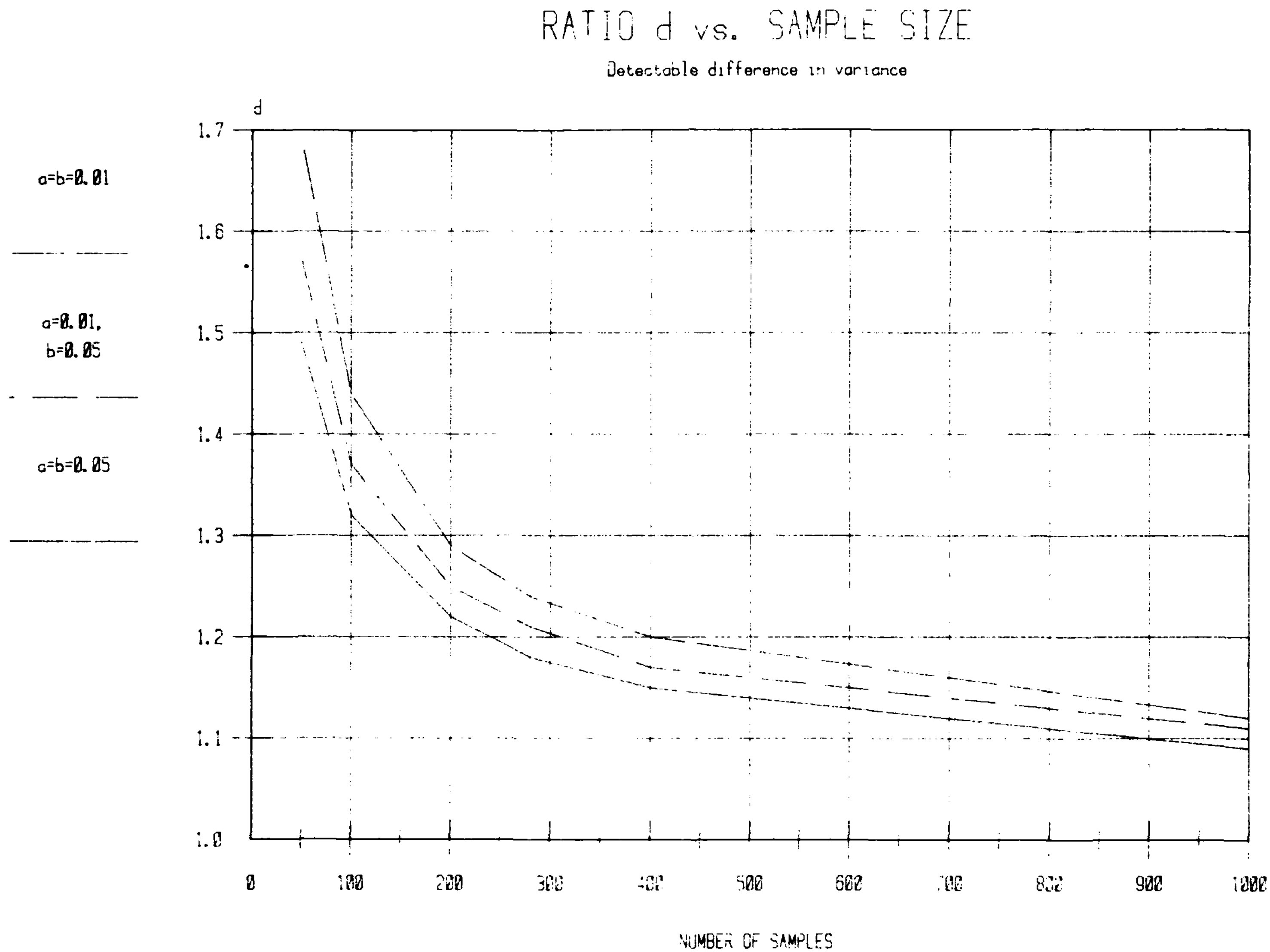

RATIO d vs. SAMPLE SIZE
Detectable difference in variance
d
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0
100
200
300
400
500
600
700
800
900
1000
NUMBER OF SAMPLES
a=b=0.01
a=0.01,
b=0.05
a=b=0.05

FIGURE 15

Now that theoretical limits have been defined for a recommended sample size; i.e., $n \approx 280$ at $\alpha = \beta = 0.05$, the adequacy can be addressed from a structural response viewpoint. Figure 6 shows one of the typical PSD estimates for the top of the rail and for combined data of eight 51 measurement sets from Track Stations 2,000 to 16,000. The size of the sample was 8 x 51 or 408 measurements. The reciprocal of any of the subdivisions of the ordinate represents some equivalent length; e.g., 0.1 cycles/ft equates to 10 ft length; 0.2 cycles/ft equates to a 5 ft distance, etc.

The more interesting portion of the PSD estimate is the low end of the spectrum where a natural frequency appears to occur at approximately 0.2 cycles per second, which is the reciprocal of 50 feet or the length of each survey section. As previously mentioned, a different set of measurements were made in 1969. The data measured in 1969 was for one position along the top center of the railhead. This data was recorded every 10 inches for 400 ft of the west rail. The slope and mean was then subtracted from the total sample. A log-linear plot of this data is shown in Figure 16. As shown by this plot, energy existed below the 0.0256 cycle per foot frequency. The next question is can this energy excite typical rocket sleds?

The previously described PSD estimates can be converted to the frequency domain multiplying both the abscissa and ordinate by a constant velocity. The constant velocity assumption should be emphasized since the velocity of rocket sleds seldom remains constant but is a quasi-steady state function. However, the time to traverse 400 feet of track varies from 0.05 sec to 8,000 feet per second (FPS) to 0.8 sec for 500 feet per second; consequently, the constant velocity assumption appears appropriate. Under the constant velocity assumption, the units of the PSD estimates become inches (RMS)/Hertz and Hertz. Using this concept, Table F was constructed. In addition to the points listed on the frequency axis; i.e., .1, .2, .3, .4, .5 cycles per foot, the frequencies of .0025, .00357, .005, .01, .0256 and .2308 cycles per foot were converted into the frequency domain because of the following special interest.

<u>.0025 Cycles per Foot</u> - Equates to a track period of 400 feet and requires minimum n = 400 each one (1) foot spaced measurements. Derived from theory $\alpha = \beta = .01$.

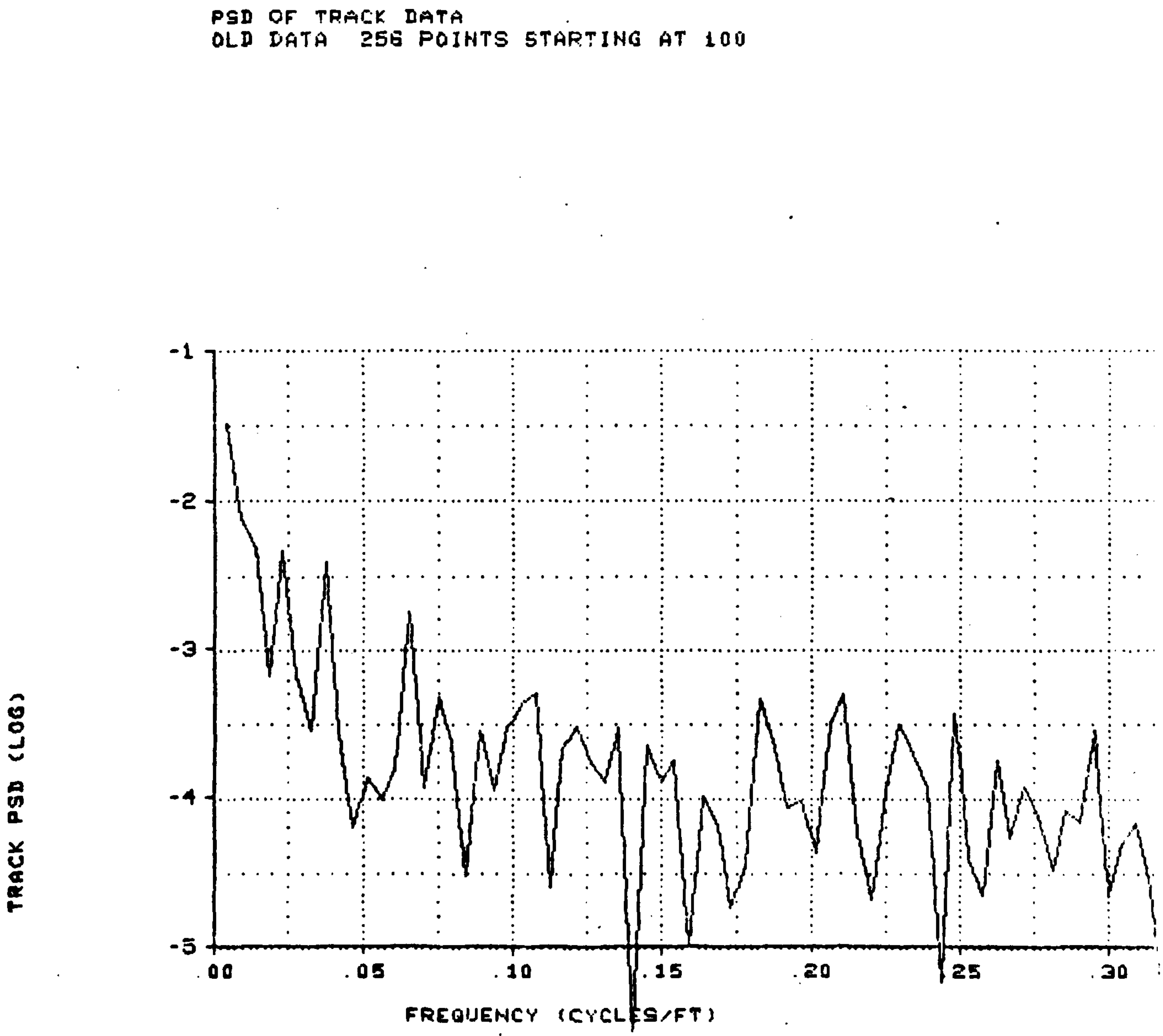

PSD OF TRACK DATA
OLD DATA 256 POINTS STARTING AT 100
-1
-2
-3
-4
-5
.00
.05
.10
.15
.20
.25
.30
TRACK PSD (LOG)
FREQUENCY (CYCLES/FT)

FIGURE 16

	n REQUIRED TO IDENTIFY											
	280	200	140	100	50	39	10	5	5	4	3	2
	FREQUENCY (CYCLES/FT)											
	.00357	.005	.0071	.01	.02	.0256	.1	.2	.2308	.3	.4	.5
VELOCITY FT/SEC	FREQUENCY (CYCLES/SECOND)											
500	1.8	2.5	3.6	5	10	12.8	50	100	115.4	150	200	250
1000	3.6	5	7.1	10	20	25.6	100	200	230.8	300	400	500
1500	5.4	7.5	10.7	15	30	38.4	150	300	346.2	450	600	750
2000	7.1	10	14.2	20	40	51.2	200	400	461.6	600	800	1000
3000	10.7	15	21.3	30	60	76.8	300	600	692.4	900	1200	1500
4000	14.3	20	28.4	40	80	102.4	400	800	923.2	1200	1600	2000
5000	17.9	25	35.5	50	100	128.0	500	1000	1154	1500	2000	2500
6000	21.4	30	42.6	60	120	153.6	600	1200	1384	1800	2400	3000
7000	25.0	35	49.7	70	140	179.2	700	1400	1616	2100	2800	3500
8000	28.6	40	56.8	80	160	204.8	800	1600	1846	2400	3200	4000

TABLE F. SAMPLE SIZE VERSUS VELOCITY/SLED FREQUENCY.

.00357 Cycles per Foot - Equates to a track period of 280 feet and requires minimum n = 280 each one (1) foot spaced measurements. Derived from theory $a = \beta = .05$.

.005 Cycles per Foot - Equates to a track period of 200 feet and requires minimum n = 200 each one (1) foot spaced measurements. Completes matrix.

.01 Cycles per Foot - Equates to a track period of 100 feet and requires minimum n = 100 each one (1) foot spaced measurements. Completes matrix.

.0256 Cycles per Foot - Equates to a track period of 39 feet and requires n = 39 each one (1) foot spaced measurements. Length of each rail section.

.2308 Cycles per Foot - Equates to a track period of 4.33 feet (52 inches) and requires a minimum of 4.33 one (1) foot spaced measurements. Distance between tie-downs and alignment points.

4.4.1 Criteria. Now that a frequency matrix has been derived, a criteria must be established in order to estimate the effect of the power at these frequencies will have on rocket sleds. Two classes of sleds will be considered.

4.4.2 Dual Rail Sleds. First, the lower frequency and lower velocity dual rail sled will be considered. Due to aerodynamic considerations, the velocities of dual rail sleds has been limited to approximately 3,000 feet per second. The structural frequency range is approximately 15 to 500 Hertz. The 15 Hz lower limit is associated with the lowest rigid body frequency observed on a dual rail sled. The 500 Hz upper limit is a conservative estimate of the highest frequency structural response that should be considered in design. Normally, the lower upper limit is used in design. This analysis does not infer that there are no vibrations above these frequencies; however, the displacement is small and need not be considered in the structural analysis process.

If these limits are applied to the previously derived frequency matrix, a band of frequencies are identified where probable response can be expected. See Table G. Based on these assumptions, the .005 cycles per foot should be measured. This requires a minimum sample size of n = 200.

4.4.3 Monorail Sleds. The monorail rocket sleds are basically higher frequency structures and are tested at much higher velocities. The maximum experimental test velocity for a monorail sled is 8,200 feet per second (FPS).

	n REQUIRED TO IDENTIFY											
	280	200	140	100	50	39	10	5	5	4	3	2
	FREQUENCY (CYCLES/FT)											
	.00357	.005	.0071	.01	.02	.0256	.1	.2	.2308	.3	.4	.5
VELOCITY FT/SEC	FREQUENCY (CYCLES/SECOND)											
500	1.8	2.5	3.6	5	10	12.8	50	100	115.4	150	200	250
1000	3.6	5	7.1	10	20	25.6	100	200	230.8	300	400	500
1500	5.4	7.5	10.7	15	30	38.4	150	300	346.2	450	600	750
2000	7.1	10	14.2	20	40	51.2	200	400	461.6	600	800	1000
3000	10.7	15	21.3	30	60	76.8	300	600	692.4	900	1200	1500
4000	14.3	20	28.4	40	80	102.4	400	800	923.2	1200	1600	2000
5000	17.9	25	35.5	50	100	128.0	500	1000	1154	1500	2000	2500
6000	21.4	30	42.6	60	120	153.6	600	1200	1384	1800	2400	3000
7000	25.0	35	49.7	70	140	179.2	700	1400	1616	2100	2800	3500
8000	28.6	40	56.8	80	160	204.8	800	1600	1846	2400	3200	4000

TABLE G. SAMPLE SIZE VS V/F DUAL RAIL SLEDS.

The lowest frequency that has been measured in the roll plane is approximately 50 Hz. An average lower limit in the pitch plane is approximately 100 Hz. On the upper limit, a conservative value of 1,000 Hz is established as the highest structural response to be of interest. Just as the case for dual rail sleds, higher frequency vibrations have been observed but not included in the design process due to the associated small displacements. These limits have been applied to Table H. On the lower end the 280 sample should suffice for monorails. The figure does indicate that measurements at a closer spacing than one (1) foot could be beneficial. However, the lower power and the fact that this interest would be at relative low velocities strongly suggest that one (1) foot spacing is adequate.

Based on this analysis and data recorded in 1969, a sample size of n = 280 is recommended on future measurements with one (1) foot spacing. The additional factor that falls out is that the data collected with 51 one foot samples are not sufficient to meet the prime objective of this study - to provide a forcing function for the sledyne simulator. This is not an indictment against the survey - those data were collected to estimate rail roughness, not to provide model parameters. This estimation of forcing functions was to be an additional benefit. The secondary objective of this study was the primary reason for the survey and previous discussions and conclusions toward that end are valid.

	n REQUIRED TO IDENTIFY											
	280	200	140	100	50	39	10	5	5	4	3	2
	FREQUENCY (CYCLES/FT)											
	.00357	.005	.0071	.01	.02	.0256	.1	.2	.2308	.3	.4	.5
VELOCITY FT/SEC	FREQUENCY (CYCLES/SECOND)											
500	1.8	2.5	3.6	5	10	12.8	50	100	115.4	150	200	250
1000	3.6	5	7.1	10	20	25.6	100	200	230.8	300	400	500
1500	5.4	7.5	10.7	15	30	38.4	150	300	346.2	450	600	750
2000	7.1	10	14.2	20	40	51.2	200	400	461.6	600	800	1000
3000	10.7	15	21.3	30	60	76.8	300	600	692.4	900	1200	1500
4000	14.3	20	28.4	40	80	102.4	400	800	923.2	1200	1600	2000
5000	17.9	25	35.5	50	100	128.0	500	1000	1154	1500	2000	2500
6000	21.4	30	42.6	60	120	153.6	600	1200	1384	1800	2400	3000
7000	25.0	35	49.7	70	140	179.2	700	1400	1616	2100	2800	3500
8000	28.6	40	56.8	80	160	204.8	800	1600	1846	2400	3200	4000

TABLE H. SAMPLE SIZE VS V/F MONORAIL SLEDS.

5. CAP THICKNESS

An extra benefit which resulted from this measurement program was a study of the thickness of the rail cap. The Test Track had specified a 0.125 inch gap between slipper surfaces and the rail head for a number of years. This tolerance equates to a slipper dimension of 1.85 inches at the cross section of the measurement point (0.75 inches in from the edge of the rail). See Figure 2. This dimension will be called slipper depth. This clearance is intended to insure that the slipper will pass over any high spots that might exist and was established by trial and error. In the past, tighter slippers have been tested on the track and the slipper depth that resulted after the test was 1.85 inches. However, the question has been asked on numerous occasions: Can this dimension be reduced? The implication was that the dynamic loads might be reduced with a smaller slipper gap.

If the maximum and minimum cap thicknesses are extracted from the data and differences taken at each of the 24 sets of data, then the cap thickness can be studied as shown in Table I.

At about the same time as the measurement program in May 1978, the first attempts were being made to make the north section (15,000 feet) operational. During the trial and error periods, it was observed that the standard 1.85 inch slipper depth would hang up at certain locations. A direct approach was used where a slipper would be pulled along the track until one of the interference locations stopped motion. The rail would then be ground at that location. Consequently, this data is probably not representative of the north track extension. A verification measurement program is planned in the near future.

A graphical representation is presented in Figure 17. This bar graph shows the data to be consistent except at track station 42,000. The possibility exists that this rail section was not from the same mill run as required in the construction of the 15,000 ft track extension. See page 14, reference 2. In addition, a difference exists in cap thickness between opposite sides of the cap due to manufacturing techniques, and construction specifications required the ends to be matched. A possibility exists that this section of rail (39 ft) was reversed.

In order to better characterize the cap thickness for the entire population, the data of each set were fitted to various distributions. The beta distribution was required to actually fit the data rigorously, but the beta distribution is

TABLE I. CAP THICKNESS

TRACK STATION	MAXIMUM (IN)	MINIMUM (IN)	DELTA (IN)	$\bar{X}$	S
2,000	1.702	1.645	.057	1.681	.0117
4,000	1.683	1.645	.038	1.673	.0081
6,000	1.686	1.622	.064	1.670	.0115
8,000	1.689	1.654	.035	1.678	.0070
10,000	1.691	1.654	.040	1.678	.0083
12,000	1.691	1.663	.028	1.677	.0060
14,000	1.702	1.630	.072	1.679	.0123
16,000	1.689	1.633	.053	1.677	.0094
18,000	1.688	1.617	.071	1.666	.0183
20,000	Water Trays	--	--	--	--
22,000	1.702	1.626	.076	1.683	.0163
24,000	1.678	1.615**	.063	1.654	.0186
26,000	1.695	1.652	.043	1.678	.0103
28,000	1.697	1.650	.047	1.678	.0088
30,000	1.693	1.623	.070	1.663	.0201
32,000	1.690	1.636	.054	1.673	.0119
34,000	1.688	1.641	.025	1.676	.0085
36,000	1.720	1.703	.017	1.711	.0037
38,000	1.702	1.634	.065	1.675	.0172
40,000	1.720	1.687	.033	1.711	.0090
42,000	1.811*	1.706	.105	1.736	.0271
44,000	1.721	1.707	.014	1.713	.0033
46,000	1.721	1.682	.039	1.710	.0070
48,000	1.705	1.687	.018	1.694	.0049
50,000	1.720	1.703	.017	1.714	.0033

*Maximum	1.811
**Minimum	1.615
Delta	0.196 inches

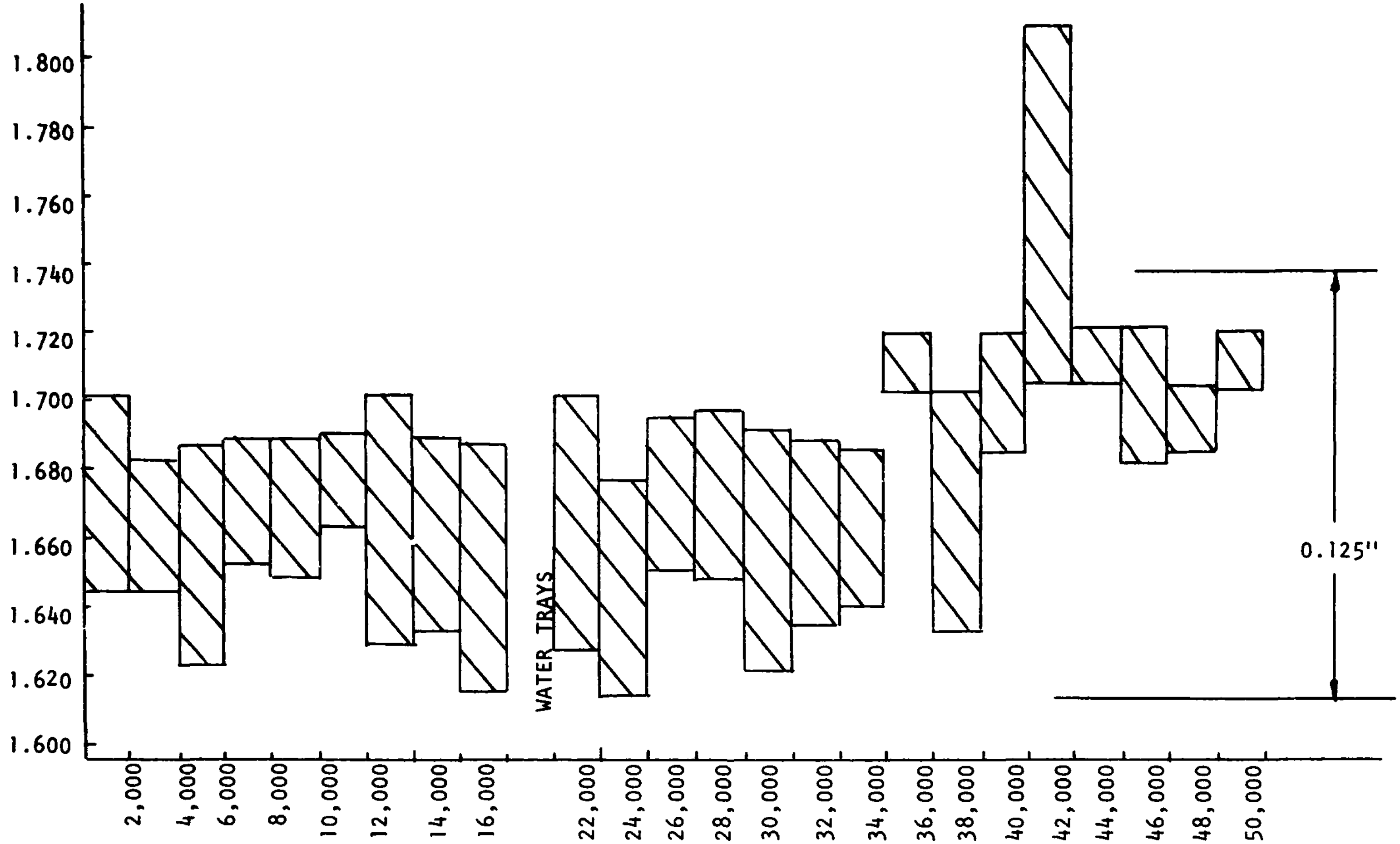


FIGURE 17. CAP THICKNESS

quite unwieldy to handle. Other distributions were also tried, and the log-normal was finally accepted as the distribution model which provided both a reasonable fit to the data and offered considerable convenience in operations.

The log-normal distribution has several desirable characteristics. For example, it lends itself to study using transformed normal data, and the overall distribution is log-normal if sets of log-normal distribution are combined by multiplication. In addition, there is a Central Limit Theorem which states that if a series of error measurements have resulted from a product of errors, the errors tend to be log-normal (reference 6). Also, typically mechanical systems do wear in a log-normal fashion. The only undesirable characteristic of the log-normal distribution is that, like the normal, it is unbounded on the upper end; i.e., it is continuous to infinity. This difficulty can be overcome by using a three parameter log-normal or Johnson S_L Distribution. The log-normal distribution uses a shape parameter, μ , and a scale parameter, σ^2, for descriptions which are not to be confused with the mean, $\bar{x}$, and variance s^2, used in description of normal distributions. The significance of μ and σ^2 are that they are the mean and variance of the natural logarithm of the parameters of interest; in this case, cap thickness. Thus, limits and confidence levels can easily be studied by taking logarithms and using standard normal table.

The log-normal parameters μ and σ^2 for each set are shown in Table J. One fact becomes clear when studying the log-normal characteristics—there are two distinct families of data: The north 15,000 feet and the south 35,000 feet. This observation was verified by analysis of variance.

Another fact was also verified--the data set from track station 42,000 appears to be an out-lier, even for the north 15,000 feet. As previously discussed, procedures were in effect in 1978 to correct these obvious anomalies; therefore, the data from 42,000 ft will be omitted from calculations. The task has been initiated to resurvey this area.

Given that the entire south 35,000 feet can be considered one population, the log-normal parameters would be μ = .5146 and σ^2 = 5.2668 x 10^{-5}. From reference 6 the probability that the data are within a given range of points is:

TABLE J. CAP THICKNESS LOG-NORMAL PARAMETERS

TRACK STATION	SHAPE PARAMETER μ	SCALE PARAMETER σ^2
2,000	.5192	4.8358
4,000	.5148	2.3520
6,000	.5127	4.8163
8,000	.5177	1.7433
10,000	.5176	2.4530
12,000	.5172	1.2833
14,000	.5182	5.4553
16,000	.5170	3.1532
18,000	.5105	12.6015
20,000	Water Trays —	--
22,000	.5106	3.8880
24,000	.5030	12.7107
26,000	.5174	3.7765
28,000	.5174	2.7856
30,000	.5088	14.7261
32,000	.5148	5.1041
34,000	.5164	2.5839
36,000	.5372	0.4697
38,000	.5260	5.0478
40,000	.5369	12.7611
42,000	.5515	23.9321
44,000	.5381	0.3714
46,000	.5365	1.7007
48,000	.5276	0.8474
50,000	.5388	0.3738

$$P \quad 1.1. \leq T \leq \text{upper limit} =$$

$$= \quad P \ln 1.1 \leq \ln T \leq \ln \ u.1.$$

$$= \Phi \frac{\ln (u.1.) - \mu}{\sigma} - \Phi \frac{\ln (1.1.) - \mu}{\sigma}$$

where 1.1 = lower limit

u.1.= upper limit

Φ = standard normal operator

for 1.1 = 1.62

u.1.= 1.72

= .5146

$\sigma^2 = 5.2668 \times 10^{-5}$

$$P = \Phi \frac{\ln (1.72) - .5146}{.007257} - \Phi \frac{\ln (1.62) - .5146}{.007257}$$

$$= \Phi\ 3.82 - \Phi\ - 4.43$$

$$= \quad .999933 - .000005 = .999928 \text{ or } 99.993\%$$

In words the logarithm of 1.72 inches is 3.82 greater than the logarithm of the mean, and logarithm of 1.62 inches is over 4.4σ below the logarithm of the mean.

The same formula can be reversed such that ± 4σ points can be calculated; i.e., set the term within brackets to equal to plus or minus 4σ and solve for the upper or lower limit

$$\frac{\ln (u.1.) - \mu}{\sigma} = 4$$

$$u.1 = \exp = 1.72219 \text{ inches}$$

So, a slipper with this depth could pass 99.9968% of the points on south 34,000 ft of the track.

The significance of the lower limit is that it establishes the maximum required slipper gap size. This dimension is important during the design of sleds because it defines the limits of the shock loads that the structure will experience as a result of vertical and cross-track velocities. Additionally, for monorails, it defines the limits for the roll motion.

A similar process can be followed for the north end of the track (minus 42,000 ft data). For T.S. 36,000 to T.S. 5,000, the log-normal parameters are $\mu = .5345$, $\sigma^2 = 3.0817 \times 10^{-5}$. The $\pm 4\sigma$ values would be 1.745 inches and 1.669 inches. As previously mentioned, surveys have been initiated to ascertain the validity of omitting the data from T.S. 42,000.

From the calculations, it appears that the depth of the slipper could be reduced at least .100 inches, or as much as .130 inches for sleds confined to the south 35,000 feet; i.e., from 1.85 to 1.75 or 1.72 inches.

6. CONCLUSIONS

The prime objective of this study — to provide a statistical forcing function for Sledyne—could not be met due to small sample sizes. From a sample of size 51 the lowest frequency component that can be studied is at .02 cycles/ft. Previous studies indicate that appreciable energy exists at frequencies a magnitude lower. Characterization of frequencies as low as .005 cycles/ft are required to meet structural dynamics requirements.

Rail grinding does result in smoother rail surfaces. Whether the difference is significant from a structural dynamics standpoint is yet to be determined. Also, the surfaces that have received the most grinding, the top, is smoother than the side which in turn is smoother than the bottom, which has received the least attention.

Analysis techniques for studying rail roughness have been developed and verified. Analysis of residuals in the frequency domain has proven a simple and effective technique.

The depth of the sled slippers can be reduced as much as .100 inches, reducing the gap between the slipper and railhead. This will reduce the tendency of monorail sleds to roll and decrease dynamic loads on all sleds.

7. RECOMMENDATIONS

A follow-on study to address the Sledyne forcing function should be accomplished. Toward this end, the experiment has been designed and survey crews tasked to collect data in sets of 280 samples (or as large as possible up to 280). Other aspects of the experiment include measuring cap thickness on both side of the rail, surveying the east and west rails, and establishing an estimate of errors in the survey process.

The Sleuyne computer simulator should be modified to allow the track parameters to be changed locally when data are available. The program should also be changed to provide a histogram output of dynamic loads.

The effects of smaller slipper gaps in dynamic load should be investigated using Sledyne.

The feasibility of selectively grinding the north 15,000 ft of the track to make the cap thickness more uniform should be investigated. This would permit use of small slipper gaps on high speed monorails in that area.

The data found in this study should be utilized to determine where to grind the rails. From the roughness classes, the roughest spots should be ground to attempt to make the track more homogeneous.

A feasibility study should be pursued on an automated measurement system for measuring the rail roughness, concentrating on multi-beam laser system(s).

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APPENDIX A

RAW DATA AND REGRESSION RESIDUALS

TRACK STATION 2000

RAW DATA			DATA WITH LINE REMOVED		
TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL	TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL
13.927	1.675	6.975	.005912	-.001326	-.014201
13.914	1.687	6.983	.005212	.010038	-.006177
13.901	1.690	6.987	.004512	.012401	-.002153
13.881	1.694	6.992	-.003188	.008765	.002871
13.870	1.686	6.992	-.001888	.002129	.002894
13.849	1.663	7.000	-.010588	-.029508	.010918
13.833	1.683	6.986	-.014288	-.013144	-.003058
13.829	1.680	6.974	-.005988	-.007780	-.015035
13.821	1.684	6.993	-.001688	.000583	.003989
13.819	1.678	7.008	.008612	.004947	.019013
13.794	1.690	7.000	-.004088	.004310	.011037
13.804	1.682	7.012	.018212	.018674	.023060
13.777	1.673	7.000	.003512	-.004962	.011084
13.761	1.690	6.990	-.000188	.008401	.001108
13.754	1.690	6.968	.005112	.013765	-.020869
13.749	1.682	6.981	.012412	.013129	-.007845
13.732	1.669	6.990	.007712	-.004508	.001179
13.705	1.663	6.986	-.006988	-.025144	-.002798
13.688	1.669	6.976	-.011688	-.023781	-.012774
13.679	1.652	6.973	-.008388	-.037417	-.015750
13.671	1.672	6.981	-.004088	-.013053	-.007726
13.661	1.660	6.976	-.001788	-.022690	-.012703
13.664	1.684	6.980	.013512	.016674	-.008679
13.652	1.685	6.992	.013812	.018037	.003345
13.627	1.694	7.000	.001112	.014401	.011368
13.604	1.686	7.000	-.009588	-.004235	.011392
13.587	1.693	6.989	-.014288	-.001872	.000416
13.579	1.683	7.000	-.009988	-.007508	.011440
13.569	1.688	7.000	-.007688	-.000144	.011463
13.562	1.682	6.990	-.002388	-.000781	.001487
13.555	1.691	6.978	.002912	.013583	-.010489
13.544	1.685	6.972	.004212	.008946	-.016466
13.517	1.686	6.977	-.010488	-.004690	-.011442
13.508	1.696	6.989	-.007188	.008674	.000582
13.508	1.688	6.995	.005112	.013037	.006606
13.493	1.677	7.001	.002412	-.000599	.012629
13.478	1.682	7.009	-.000288	.001765	.020653
13.463	1.702	7.000	-.002988	.019128	.011677
13.454	1.685	6.985	.000312	.005492	-.003300
13.442	1.682	6.983	.000612	.002855	-.005276
13.435	1.679	6.982	.005912	.005219	-.006252
13.421	1.681	6.997	.004212	.005583	.008772
13.407	1.695	7.008	.002512	.017946	.019795
13.413	1.699	7.000	.020812	.040310	.011819
13.392	1.677	6.980	.012112	.009673	-.008157
13.372	1.675	6.974	.004412	.000037	-.014134
13.362	1.660	6.974	.006712	-.012599	-.014110
13.353	1.645	6.984	.010012	-.024236	-.004086
13.318	1.669	6.984	-.012688	-.022872	-.004063
13.303	1.675	6.986	-.015388	-.019508	-.002039
13.292	1.677	6.987	-.014088	-.016145	-.001015

TRACK STATION 4000

RAW DATA			DATA WITH LINE REMOVED		
TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL	TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL
6.067	1.679	5.625	-.003225	.005319	.003676
6.047	1.660	5.630	-.011598	-.022169	.009045
6.049	1.645	5.607	.002029	-.023657	-.013587
6.033	1.652	5.594	-.002344	-.021145	-.026219
6.005	1.675	5.600	-.018717	-.014633	-.019851
6.010	1.676	5.608	-.002090	.002879	-.011482
6.005	1.671	5.617	.004537	.004391	-.002114
6.000	1.682	5.626	.011164	.021903	.007254
5.990	1.683	5.644	.012791	.024415	.025622
5.972	1.678	5.627	.006418	.012927	.008991
5.953	1.675	5.613	-.000955	.002438	-.004641
5.940	1.676	5.609	-.002328	.001950	-.008273
5.928	1.672	5.625	-.002701	-.002538	.008095
5.921	1.673	5.642	.001926	.002974	.025464
5.907	1.681	5.628	-.000447	.008486	.011832
5.895	1.673	5.628	-.000820	-.000002	.012200
5.877	1.680	5.614	-.007193	.000510	-.001432
5.871	1.673	5.622	-.001565	-.000978	.006936
5.859	1.676	5.628	-.001938	.001534	.013305
5.847	1.675	5.627	-.002311	.000046	.012673
5.827	1.670	5.614	-.010684	-.013442	.000041
5.819	1.661	5.614	-.007057	-.018930	.000409
5.815	1.668	5.612	.000570	-.004418	-.001222
5.785	1.678	5.607	-.017803	-.012906	-.005854
5.776	1.677	5.605	-.015176	-.011394	-.007486
5.768	1.678	5.602	-.011549	-.006882	-.010118
5.773	1.674	5.602	.005078	.005630	-.009749
5.767	1.676	5.605	.010705	.013142	-.006381
5.750	1.679	5.605	.005332	.010653	-.006013
5.739	1.664	5.612	.005959	-.003835	.001355
5.738	1.652	5.605	.016586	-.005323	-.005276
5.721	1.670	5.602	.011213	.007189	-.007908
5.707	1.677	5.606	.008840	.011701	-.003540
5.707	1.673	5.600	.020467	.019213	-.009172
5.706	1.683	5.592	.031095	.039725	-.016804
5.672	1.682	5.598	.008722	.016237	-.010435
5.648	1.671	5.605	-.003651	-.007251	-.003067
5.634	1.663	5.611	-.006024	-.017739	.003301
5.637	1.675	5.602	.008603	.008773	-.005331
5.639	1.672	5.635	.022230	.019285	.028038
5.624	1.677	5.635	.018857	.020797	.028406
5.605	1.681	5.609	.011484	.017309	.002774
5.584	1.681	5.598	.002111	.007821	-.007858
5.571	1.676	5.596	.000738	.001333	-.009489
5.548	1.677	5.605	-.010635	-.009155	-.000121
5.530	1.674	5.603	-.017008	-.018643	-.001753
5.520	1.673	5.605	-.015381	-.018131	.000615
5.511	1.676	5.608	-.012754	-.012620	.003984
5.495	1.683	5.612	-.017127	-.010108	.0[illegible]8352
5.486	1.678	5.600	-.014500	-.012596	-.003280
5.479	1.666	5.599	-.009873	-.020084	-.003912

TRACK STATION 6000

RAW DATA			DATA WITH LINE REMOVED		
TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL	TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL
14.246	1.645	6.434	-.007333	-.036182	.027717
14.252	1.658	6.419	.012417	-.003270	.011992
14.243	1.668	6.405	.017168	.011641	-.002733
14.225	1.685	6.428	.012918	.024553	.019542
14.205	1.676	6.435	.006669	.009465	.025817
14.175	1.665	6.416	-.009580	-.017624	.006091
14.165	1.669	6.412	-.005830	-.009712	.001366
14.152	1.679	6.402	-.005079	.001199	-.009359
14.152	1.678	6.413	.008671	.014111	.000916
14.143	1.676	6.406	.013422	.017023	-.006809
14.127	1.686	6.409	.011173	.024934	-.004534
14.102	1.679	6.404	-.000077	.006846	-.010260
14.089	1.668	6.409	.000674	-.003243	-.005985
14.068	1.671	6.407	-.006576	-.007331	-.008710
14.062	1.671	6.412	.001175	.000580	-.004435
14.053	1.678	6.405	.005925	.012492	-.012160
14.035	1.667	6.404	.001676	-.002596	-.013885
14.021	1.677	6.399	.001427	.007315	-.019610
14.010	1.674	6.404	.004177	.007227	-.015336
13.993	1.681	6.402	.000928	.011138	-.018061
13.979	1.678	6.405	.000678	.008050	-.015786
13.969	1.680	6.412	.004429	.013962	-.009511
13.956	1.673	6.415	.005180	.007873	-.007236
13.943	1.668	6.415	.005930	.003785	-.007961
13.916	1.675	6.417	-.007319	-.002304	-.006687
13.889	1.678	6.422	-.020569	-.012392	-.002412
13.882	1.668	6.434	-.013818	-.015481	.008863
13.861	1.678	6.430	-.021067	-.012569	.004138
13.854	1.664	6.421	-.014317	-.019657	-.005587
13.846	1.655	6.428	-.008566	-.022746	.000688
13.835	1.663	6.423	-.005816	-.011834	-.005038
13.812	1.653	6.434	-.015065	-.030923	.005237
13.800	1.667	6.426	-.013315	-.015011	-.003488
13.782	1.684	6.441	-.017564	-.002099	.010787
13.778	1.675	6.458	-.007813	-.001188	.027062
13.768	1.673	6.455	-.004063	.000724	.023337
13.759	1.673	6.440	.000688	.005635	.007611
13.738	1.669	6.440	-.006562	-.005453	.006886
13.719	1.681	6.448	-.011811	.001458	.014161
13.710	1.663	6.445	-.007060	-.011630	.010436
13.701	1.670	6.438	-.002310	.000282	.002711
13.687	1.675	6.441	-.002559	.005193	.004986
13.682	1.651	6.436	.006191	-.009895	-.000739
13.674	1.622	6.453	.011942	-.032984	.015535
13.652	1.644	6.449	.003693	-.019072	.010810
13.638	1.668	6.426	.003443	.004840	-.012915
13.624	1.674	6.425	.003194	.010751	-.014640
13.625	1.676	6.435	.017944	.027663	-.005365
13.614	1.673	6.425	.020695	.027574	-.016090
13.598	1.671	6.439	.018445	.023486	-.002816
13.579	1.668	6.444	.013196	.015397	.001459

TRACK STATION 8000

RAW DATA TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL	DATA WITH LINE REMOVED TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL
13.981	1.654	6.975	.009531	-.015239	.031597
13.960	1.678	6.968	.009821	.009076	.023931
13.932	1.677	6.945	.003111	.001390	.000265
13.907	1.675	6.945	-.000599	-.004295	-.000401
13.883	1.677	6.945	-.003309	-.004980	-.001068
13.856	1.678	6.945	-.009018	-.009666	-.001734
13.840	1.678	6.945	-.003728	-.004351	-.002400
13.814	1.680	6.945	-.008438	-.007036	-.003066
13.800	1.683	6.950	-.001148	.003278	.001267
13.771	1.677	6.968	-.008858	-.010407	.018601
13.749	1.671	6.968	-.009568	-.017092	.017935
13.721	1.667	6.976	-.016278	-.027778	.025269
13.707	1.680	6.950	-.008987	-.007463	-.001398
13.674	1.685	6.941	-.020697	-.014148	-.011064
13.669	1.689	6.932	-.004407	.006166	-.020730
13.667	1.686	6.932	.014883	.022481	-.021396
13.627	1.685	6.938	-.003827	.002796	-.016063
13.611	1.678	6.951	.001463	.001110	-.003729
13.590	1.672	6.955	.001753	-.004575	-.000395
13.571	1.678	6.955	.004043	.003739	-.001061
13.562	1.683	6.955	.016334	.021054	-.001728
13.539	1.688	6.955	.014624	.024369	-.002394
13.513	1.682	6.955	.009914	.013683	-.003060
13.486	1.688	6.955	.004204	.013998	-.003726
13.467	1.686	6.955	.006494	.014313	-.004393
13.448	1.678	6.955	.008784	.008627	-.005059
13.421	1.676	6.955	.003074	.000942	-.005725
13.396	1.676	6.950	-.000635	-.002743	-.011391
13.380	1.675	6.940	.004655	.001571	-.022058
13.346	1.684	6.940	-.008055	-.002114	-.022724
13.322	1.683	6.952	-.010765	-.005799	-.011390
13.307	1.684	6.965	-.004475	.001515	.000944
13.296	1.688	6.965	.005815	.015830	.000277
13.277	1.675	6.965	.008105	.005145	-.000389
13.248	1.678	6.963	.000396	.000459	-.003055
13.230	1.674	6.963	.003686	-.000226	-.003721
13.203	1.683	6.954	-.002024	.003089	-.013388
13.182	1.684	6.954	-.001734	.004403	-.014054
13.169	1.683	6.954	.006556	.011718	-.014720
13.147	1.680	6.957	.005846	.008033	-.012386
13.139	1.675	6.961	.019136	.016347	-.009052
13.099	1.678	6.966	.000426	.000662	-.004719
13.088	1.663	6.983	.010717	-.004023	.011615
13.060	1.682	7.000	.004007	.008291	.027949
13.044	1.674	7.012	.009297	.005606	.039283
13.022	1.675	7.008	.008587	.005921	.034616
12.995	1.667	6.999	.002877	-.007765	.024950
12.954	1.675	6.985	-.016833	-.019450	.010284
12.921	1.686	6.971	-.028543	-.020135	-.004382
12.915	1.670	6.971	-.013252	-.020821	-.005049
12.894	1.665	6.971	-.012962	-.025506	-.005715

TRACK STATION 10000

RAW DATA

DATA WITH LINE REMOVED

TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL	TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL
14.253	1.677	7.516	-.002945	-.002399	-.021989
14.227	1.681	7.536	-.010946	-.006462	-.002243
14.198	1.682	7.539	-.021946	-.016525	.000503
14.186	1.682	7.532	-.015947	-.010589	-.006751
14.178	1.667	7.534	-.005947	-.015652	-.005004
14.166	1.670	7.531	.000052	-.006715	-.008258
14.142	1.665	7.530	-.005949	-.017778	-.009512
14.132	1.678	7.520	.002051	.003158	-.019766
14.113	1.679	7.528	.001050	.003095	-.012019
14.086	1.672	7.541	-.007951	-.012968	.000727
14.066	1.680	7.545	-.009951	-.007032	.004473
14.049	1.666	7.530	-.008952	-.020095	-.010781
14.039	1.679	7.529	-.000953	.000842	-.012035
14.026	1.682	7.530	.004047	.008779	-.011288
14.008	1.682	7.530	.004046	.008715	-.011542
13.972	1.680	7.531	-.013954	-.011348	-.010796
13.961	1.674	7.538	-.006955	-.010411	-.004050
13.949	1.686	7.556	-.000956	.007526	.013697
13.936	1.686	7.556	.004044	.012462	.013443
13.922	1.686	7.552	.008043	.016399	.009189
13.898	1.681	7.552	.002042	.005336	.008935
13.882	1.681	7.564	.004042	.007273	.020682
13.865	1.683	7.567	.005041	.010209	.023428
13.858	1.680	7.558	.016040	.018146	.014174
13.844	1.687	7.548	.020040	.029083	.003920
13.833	1.678	7.550	.027039	.027020	.005667
13.815	1.672	7.555	.027039	.020956	.010413
13.784	1.672	7.567	.014038	.007893	.022159
13.764	1.679	7.556	.012037	.012830	.010905
13.752	1.663	7.548	.018037	.002767	.002652
13.734	1.654	7.544	.018036	-.006297	-.001602
13.705	1.679	7.549	.007035	.007640	.003144
13.682	1.686	7.568	.002035	.009577	.021890
13.668	1.690	7.575	.006034	.017514	.028637
13.651	1.680	7.576	.007034	.008450	.029383
13.626	1.678	7.569	.000033	-.000613	.022129
13.609	1.683	7.564	.001032	.005324	.016875
13.588	1.684	7.557	-.001968	.003261	.009622
13.573	1.686	7.543	.001031	.008197	-.004632
13.552	1.666	7.543	-.001970	-.014866	-.004886
13.545	1.655	7.543	.009030	-.014929	-.005140
13.512	1.669	7.540	-.005971	-.015993	-.008393
13.494	1.680	7.535	-.005972	-.005056	-.013647
13.484	1.679	7.545	.002028	.001881	-.003901
13.476	1.674	7.554	.012027	.006818	.004845
13.433	1.684	7.546	-.012973	-.008246	-.003408
13.406	1.679	7.539	-.021974	-.022309	-.010662
13.387	1.689	7.527	-.022975	-.013372	-.022916
13.370	1.691	7.524	-.021975	-.010435	-.026170
13.352	1.690	7.526	-.021976	-.011499	-.024423
13.353	1.673	7.525	-.002977	-.009562	-.025677

TRACK STATION 12000

RAW DATA			DATA WITH LINE REMOVED		
TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL	TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL
5.713	1.675	7.345	-.024525	-.027219	.010096
5.694	1.682	7.337	-.025210	-.020886	.001741
5.684	1.686	7.329	-.016895	-.008553	-.006615
5.674	1.678	7.326	-.008580	-.008221	-.009970
5.650	1.678	7.333	-.014264	-.013888	-.003325
5.638	1.673	7.343	-.007949	-.012555	.006320
5.619	1.676	7.368	-.008634	-.010223	.030965
5.599	1.671	7.376	-.010319	-.016890	.038609
5.581	1.677	7.363	-.010004	-.010557	.025254
5.565	1.682	7.336	-.007689	-.003225	-.002101
5.550	1.680	7.318	-.004374	-.001892	-.020456
5.535	1.676	7.325	-.001059	-.002559	-.013811
5.515	1.673	7.336	-.002744	-.007227	-.003167
5.498	1.676	7.332	-.001428	-.002894	-.007522
5.482	1.687	7.334	.000887	.010439	-.005877
5.470	1.681	7.330	.007202	.010771	-.010232
5 455	1.686	7.338	.010517	.019104	-.002587
5.427	1.678	7.334	.000832	.001437	-.006943
5.410	1.682	7.325	.002147	.006769	-.016298
5.385	1.675	7.340	-.004538	-.006898	-.001653
5.367	1.677	7.337	-.004223	-.004565	-.005008
5.360	1.675	7.334	.007092	.004767	-.008363
5.349	1.669	7.339	.014408	.006100	-.003719
5.334	1.672	7.338	.017723	.012433	-.005074
5.310	1.663	7.352	.012038	-.002235	.008571
5.305	1.669	7.350	.025353	.017098	.006216
5.284	1.674	7.350	.022668	.019431	.005860
5.279	1.682	7.347	.035983	.040763	.002505
5.274	1.682	7.347	.049298	.054096	.002150
5.236	1.685	7.338	.029613	.037429	-.007205
5.206	1.679	7.344	.017929	.019761	-.001560
5.187	1.675	7.330	.017244	.015094	-.015916
5.168	1.674	7.324	.016559	.013427	-.022271
5.146	1.689	7.337	.012874	.024759	-.009626
5.130	1.676	7.349	.015189	.014092	.002019
5.105	1.668	7.356	.008504	-.000575	.008664
5.095	1.674	7.336	.016819	.013757	-.011692
5.076	1.675	7.335	.016134	.014090	-.013047
5.045	1.678	7.338	.003449	.004423	-.010402
5.014	1.667	7.353	-.009235	-.019245	.004243
4.986	1.673	7.368	-.018920	-.022912	.018888
4.971	1.675	7.371	-.015605	-.017579	.021532
4.951	1.681	7.372	-.017290	-.013247	.022177
4.938	1.682	7.365	-.011975	-.006914	.014822
4.918	1.677	7.342	-.013660	-.013581	-.008533
4.897	1.687	7.347	-.016345	-.006249	-.003888
4.881	1.684	7.354	-.014030	-.006916	.002756
4.851	1.691	7.342	-.025715	-.011583	-.009599
4.837	1.676	7.357	-.021399	-.022251	.005046
4.812	1.672	7.358	-.028084	-.032918	.005691
4.806	1.667	7.355	-.015769	-.025585	.002336

TRACK STATION 14000

RAW DATA			DATA WITH LINE REMOVED		
TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL	TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL
12.985	1.691	6.861	.009854	.020315	.004505
12.961	1.685	6.863	.007588	.012111	.006341
12.940	1.689	6.860	.008323	.016907	.003177
12.917	1.678	6.862	.007057	.004703	.005013
12.891	1.679	6.857	.002792	.001499	-.000150
12.864	1.672	6.860	-.002474	-.010705	.002686
12.840	1.678	6.854	-.004739	-.006909	-.003478
12.825	1.691	6.850	.001995	.012887	-.007641
12.807	1.679	6.856	.005730	.004683	-.001805
12.781	1.682	6.861	.001464	.003479	.003031
12.748	1.674	6.863	-.009802	-.015725	.004867
12.731	1.674	6.857	-.005067	-.010929	-.001296
12.713	1.687	6.853	-.001333	.005867	-.005460
12.691	1.678	6.850	-.001598	-.003337	-.008624
12.655	1.681	6.856	-.015864	-.014541	-.002787
12.645	1.675	6.891	-.004129	-.008744	.032049
12.632	1.670	6.887	.004605	-.004948	.027885
12.615	1.682	6.874	.009340	.011848	.014721
12.579	1.682	6.865	-.004926	-.002356	.005558
12.560	1.679	6.851	-.002191	-.002560	-.008606
12.526	1.659	6.851	-.014457	-.034764	-.008770
12.518	1.650	6.849	-.000722	-.029968	-.010933
12.502	1.664	6.852	.005012	-.010172	-.008097
12.464	1.680	6.852	-.011253	-.010376	-.008261
12.451	1.691	6.852	-.002519	.009420	-.008425
12.433	1.684	6.860	.001216	.006216	-.000588
12.418	1.683	6.861	.007950	.012012	.000248
12.393	1.677	6.861	.004685	.002808	.000084
12.362	1.681	6.853	-.004581	-.002396	-.008079
12.329	1.680	6.854	-.015846	-.014600	-.007243
12.313	1.680	6.860	-.010112	-.008804	-.001407
12.293	1.686	6.854	-.008377	-.001008	-.007570
12.271	1.687	6.855	-.008643	-.000212	-.006734
12.269	1.692	6.857	.011092	.024584	-.004898
12.252	1.682	6.859	.015826	.019380	-.003062
12.235	1.684	6.859	.020560	.026176	-.003225
12.200	1.683	6.856	.007295	.011972	-.006389
12.161	1.690	6.847	-.009971	.001768	-.015553
12.140	1.702	6.842	-.009236	.014564	-.020716
12.113	1.698	6.846	-.014502	.005360	-.016880
12.103	1.683	6.851	-.002767	.002156	-.012044
12.083	1.668	6.859	-.001033	-.011048	-.004208
12.065	1.657	6.868	.002702	-.018252	.004629
12.058	1.630	6.875	.017436	-.030456	.011465
12.035	1.653	6.874	.016171	-.008660	.010301
11.999	1.684	6.876	.001905	.008136	.012138
11.975	1.685	6.879	-.000360	.006932	.014974
11.957	1.687	6.876	.003374	.012728	.011810
11.940	1.676	6.871	.008109	.006524	.006646
11.910	1.683	6.871	-.000157	.005320	.006483
11.873	1.684	6.879	-.015422	-.008884	.014319

TRACK STATION 16000

RAW DATA			DATA WITH LINE REMOVED		
TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL	TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL
5.618	1.687	7.122	.001071	.007065	-.016972
5.616	1.686	7.122	.017171	.022327	-.016605
5.603	1.687	7.140	.022271	.028588	.001763
5.556	1.673	7.144	-.006629	-.014150	.006130
5.535	1.673	7.144	-.009529	-.016888	.006498
5.514	1.677	7.144	-.012430	-.015627	.006865
5.500	1.675	7.144	-.008330	-.013365	.007233
5.470	1.680	7.140	-.020230	-.020103	.003600
5.469	1.684	7.140	-.003130	.001159	.003968
5.455	1.688	7.140	.000970	.009420	.004336
5.432	1.677	7.140	-.003930	-.006318	.004703
5.407	1.678	7.140	-.010830	-.012056	.005071
5.404	1.676	7.140	.004270	.001205	.005438
5.383	1.673	7.135	.001370	-.004533	.000806
5.367	1.689	7.135	.003470	.013729	.001173
5.339	1.685	7.135	-.006430	-.000009	.001541
5.312	1.686	7.135	-.015331	-.007748	.001908
5.306	1.670	7.143	-.003231	-.011486	.010276
5.299	1.679	7.153	.007869	.008776	.020643
5.279	1.674	7.150	.005969	.002038	.018011
5.253	1.675	7.139	-.001931	-.004701	.007378
5.231	1.683	7.132	-.005831	-.000439	.000746
5.215	1.668	7.132	-.003731	-.013177	.001113
5.200	1.672	7.121	-.000631	-.005915	-.009519
5.182	1.675	7.121	-.000531	-.002654	-.009152
5.167	1.680	7.121	.002569	.005608	-.008784
5.163	1.679	7.118	.016669	.018870	-.011417
5.139	1.687	7.118	.010768	.021131	-.011049
5.121	1.685	7.116	.010868	.019393	-.012682
5.104	1.685	7.128	.011968	.020655	-.000314
5.082	1.683	7.142	.008068	.014916	.014053
5.062	1.679	7.142	.006168	.009178	.014421
5.039	1.673	7.138	.001268	-.001560	.010788
5.021	1.674	7.121	.001368	-.000298	-.005844
5.003	1.675	7.108	.001468	.000963	-.018477
4.992	1.665	7.104	.008568	-.001775	-.022109
4.983	1.665	7.102	.017668	.007487	-.023742
4.955	1.664	7.102	.007768	-.003252	-.023374
4.924	1.674	7.108	-.005133	-.005990	-.017007
4.902	1.675	7.112	-.009033	-.008728	-.012639
4.876	1.633	7.115	-.016933	-.058466	-.009272
4.866	1.657	7.110	-.008833	-.026205	-.013904
4.857	1.677	7.110	.000267	.003057	-.013537
4.844	1.687	7.110	.005367	.018319	-.013169
4.820	1.681	7.120	-.000533	.006581	-.002802
4.811	1.682	7.122	.008567	.016842	-.000434
4.796	1.674	7.128	.011667	.012104	.005933
4.760	1.678	7.137	-.006233	-.001634	.015301
4.739	1.676	7.155	-.009133	-.006373	.033668
4.717	1.681	7.155	-.013034	-.005111	.034036
4.698	1.686	7.146	-.013934	-.000849	.025403

TRACK STATION 18000

RAW DATA			DATA WITH LINE REMOVED		
TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL	TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL
13.881	1.680	6.855	.012039	.022217	-.002080
13.866	1.677	6.865	.012696	.020018	.007421
13.848	1.680	6.884	.010352	.020819	.025921
13.832	1.676	6.876	.010009	.016619	.017421
13.808	1.681	6.878	.001665	.013420	.018922
13.802	1.681	6.876	.011322	.023221	.016422
13.754	1.676	6.865	-.021022	-.013978	.004923
13.769	1.688	6.851	.009635	.028822	-.009577
13.757	1.685	6.848	.013291	.029623	-.013076
13.740	1.677	6.847	.011947	.020424	-.014576
13.717	1.677	6.853	.004604	.013224	-.009075
13.685	1.681	6.855	-.011740	.001025	-.007575
13.681	1.680	6.860	-.000083	.011826	-.003075
13.665	1.672	6.862	-.000427	.003627	-.001574
13.644	1.669	6.860	-.005770	-.004573	-.004074
13.632	1.659	6.854	-.002114	-.010772	-.010573
13.617	1.650	6.858	-.001457	-.018971	-.007073
13.600	1.644	6.858	-.002801	-.026170	-.007572
13.579	1.655	6.858	-.008144	-.020370	-.008072
13.567	1.668	6.870	-.004488	-.003569	.003429
13.557	1.668	6.893	.001169	.002232	.025929
13.534	1.681	6.886	-.006175	.008032	.018430
13.522	1.675	6.861	-.002518	.005833	-.007070
13.486	1.657	6.858	-.022862	-.032366	-.010570
13.479	1.626	6.862	-.014205	-.054565	-.007069
13.475	1.631	6.862	-.002549	-.037765	-.007569
13.457	1.632	6.860	-.004893	-.038964	-.010068
13.443	1.648	6.860	-.003236	-.021163	-.010568
13.427	1.647	6.870	-.003580	-.022363	-.001067
13.415	1.636	6.868	.000077	-.029562	-.003567
13.403	1.617	6.875	.003733	-.044761	.002934
13.375	1.621	6.866	-.008610	-.052960	-.006566
13.353	1.656	6.861	-.014954	-.024160	-.012065
13.345	1.650	6.866	-.007297	-.022359	-.007565
13.340	1.686	6.878	.003359	.024442	.003935
13.318	1.683	6.880	-.002984	.015243	.005436
13.300	1.679	6.868	-.005328	.009043	-.007064
13.284	1.660	6.863	-.005671	-.010156	-.012563
13.271	1.673	6.860	-.003015	.005645	-.016063
13.252	1.678	6.862	-.006358	.007445	-.014562
13.240	1.678	6.869	-.002702	.011246	-.008062
13.227	1.683	6.883	-.000045	.019047	.005439
13.213	1.681	6.891	.001611	.018848	.012939
13.192	1.674	6.900	-.003733	.006648	.021440
13.178	1.657	6.881	-.002076	-.008551	.001940
13.164	1.670	6.873	-.000420	.006250	-.006560
13.158	1.678	6.898	.009237	.024050	.017941
13.143	1.667	6.920	.009893	.013851	.039441
13.135	1.673	6.896	.017550	.027652	.014942
13.118	1.673	6.873	.016206	.026453	-.008558
13.107	1.683	6.872	.020863	.041253	-.010057

TRACK STATION 22000

RAW DATA			DATA WITH LINE REMOVED		
TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL	TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL
12.707	1.674	7.018	.009787	.020520	.023413
12.686	1.667	7.009	-.000484	.003125	.014798
12.675	1.649	7.004	-.000756	-.015270	.010183
12.676	1.676	6.994	.010973	.023336	.000568
12.661	1.653	6.996	.006701	-.004059	.002953
12.655	1.674	6.982	.011430	.021546	-.010662
12.658	1.678	6.976	.025158	.039151	-.016277
12.657	1.674	6.994	.034887	.044756	.002108
12.632	1.678	6.991	.020615	.034361	-.000507
12.609	1.662	6.995	.008344	.005966	.003878
12.583	1.670	6.982	-.006928	-.001429	-.008737
12.581	1.663	6.988	.001801	.000176	-.002352
12.567	1.661	6.984	-.001471	-.005219	-.005967
12.546	1.665	6.985	-.011742	-.011614	-.004582
12.537	1.651	6.987	-.010014	-.024009	-.002197
12.533	1.647	6.978	-.003285	-.021404	-.010811
12.522	1.660	6.973	-.003557	-.008799	-.015426
12.511	1.666	6.976	-.003828	-.003193	-.012041
12.492	1.659	6.980	-.012100	-.018588	-.007656
12.483	1.660	6.986	-.010371	-.015983	-.001271
12.482	1.673	6.996	-.000643	.006622	.009114
12.480	1.674	6.992	.008086	.016227	.005499
12.451	1.680	6.983	-.010186	.003832	-.003116
12.428	1.673	6.974	-.022457	-.015563	-.011731
12.416	1.653	6.970	-.023729	-.036958	-.015346
12.409	1.652	6.974	-.020000	-.034353	-.010961
12.405	1.656	6.982	-.013271	-.023748	-.002576
12.399	1.662	6.988	-.008543	-.013143	.003809
12.389	1.664	6.995	-.007814	-.010538	.011194
12.381	1.662	7.002	-.005086	-.009933	.018579
12.374	1.649	7.010	-.001357	-.019328	.026965
12.353	1.678	6.990	-.011629	-.000723	.007350
12.348	1.681	6.978	-.005900	.007883	-.004265
12.353	1.672	6.973	.009828	.014488	-.008880
12.333	1.676	6.988	.000557	.009093	.006505
12.321	1.669	6.989	-.000715	.000698	.007890
12.300	1.656	6.987	-.010986	-.022697	.006275
12.283	1.654	6.986	-.017258	-.031092	.005660
12.266	1.664	6.979	-.023529	-.027487	-.000955
12.260	1.668	6.979	-.018801	-.018882	-.000570
12.260	1.665	6.978	-.008072	-.011277	-.001185
12.260	1.652	6.979	.002656	-.013672	.000200
12.247	1.654	6.990	.000385	-.014067	.011585
12.241	1.662	6.984	.005113	-.001462	.005970
12.233	1.675	6.977	.007842	.014143	-.000644
12.216	1.686	6.970	.001570	.018748	-.007259
12.216	1.673	6.981	.012299	.016353	.004126
12.206	1.669	6.978	.013027	.012959	.001511
12.200	1.679	6.971	.017756	.027564	-.005104
12.200	1.679	6.967	.028484	.038169	-.008719
12.198	1.687	6.965	.037213	.054774	-.010334

TRACK STATION 24000

RAW DATA			DATA WITH LINE REMOVED		
TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL	TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL
9.270	1.619	6.996	.007725	-.005196	.002187
9.267	1.631	6.991	.012208	.010411	-.001540
9.261	1.643	6.987	.013690	.023018	-.004266
9.252	1.647	6.987	.012173	.024625	-.002993
9.249	1.641	6.991	.016655	.022232	.002280
9.239	1.628	6.991	.014137	.005839	.003554
9.223	1.626	6.983	.005620	-.005554	-.003173
9.206	1.618	6.981	-.003898	-.023947	-.003900
9.204	1.621	6.993	.001584	-.016340	.009373
9.183	1.628	7.010	-.011933	-.023733	.027647
9.182	1.635	6.991	-.005451	-.011125	.009920
9.175	1.626	6.983	-.004969	-.020518	.003193
9.180	1.616	6.974	.007514	-.018911	-.004533
9.171	1.615	6.976	.005996	-.022304	-.001260
9.146	1.631	6.976	-.011522	-.024697	.000013
9.132	1.643	6.976	-.018039	-.020090	.001287
9.127	1.659	6.978	-.015557	-.002483	.004560
9.133	1.670	6.980	-.002075	.021124	.007833
9.118	1.678	6.980	-.009592	.020731	.009106
9.108	1.677	6.979	-.012110	.016338	.009380
9.103	1.661	6.955	-.009627	.001945	-.013347
9.102	1.659	6.950	-.003145	.005552	-.017074
9.079	1.668	6.946	-.018663	-.001841	-.019800
9.074	1.676	6.945	-.016180	.007766	-.019527
9.068	1.669	6.950	-.014698	.001373	-.013254
9.072	1.672	6.960	-.003216	.014980	-.001980
9.076	1.665	6.960	.008267	.018587	-.000707
9.059	1.657	6.960	-.001251	.000195	.000566
9.042	1.658	6.961	-.010769	-.009198	.002840
9.044	1.659	6.956	-.001286	.000409	-.000887
9.050	1.661	6.948	.012196	.015016	-.007614
9.023	1.660	6.949	-.007322	-.006377	-.005341
9.015	1.667	6.946	-.007839	-.000770	-.007067
9.005	1.668	6.946	-.010357	-.003163	-.005794
9.002	1.671	6.946	-.005875	.003444	-.004521
8.995	1.665	6.943	-.005392	-.002949	-.006247
8.996	1.653	6.943	.003090	-.007342	-.004974
8.999	1.657	6.943	.013573	.006265	-.003701
8.995	1.662	6.943	.017055	.013872	-.002427
8.998	1.660	6.952	.027537	.021479	.007846
8.987	1.659	6.960	.024020	.016086	.017119
8.982	1.665	6.962	.026502	.023693	.020392
8.950	1.672	6.958	.001984	.005300	.017666
8.941	1.661	6.948	.000467	-.008093	.008939
8.938	1.663	6.942	.004949	-.002485	.004212
8.924	1.654	6.940	-.001569	-.018878	.003486
8.932	1.661	6.923	.013914	.002729	-.012241
8.900	1.668	6.925	-.010604	-.015664	-.008968
8.890	1.677	6.925	-.013122	-.010057	-.007694
8.892	1.670	6.942	-.003639	-.008450	.010579
8.877	1.674	6.931	-.011157	-.012843	.000852

TRACK STATION 26000

RAW DATA			DATA WITH LINE REMOVED		
TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL	TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL
15.556	1.679	6.639	-.005538	-.002193	.021090
15.545	1.683	6.635	-.010371	-.003107	.015296
15.536	1.683	6.638	-.013204	-.006021	.016503
15.526	1.666	6.636	-.017038	-.026935	.012710
15.526	1.671	6.632	-.010871	-.015848	.006916
15.524	1.673	6.638	-.006705	-.009762	.011123
15.521	1.682	6.640	-.003538	.002324	.011329
15.518	1.683	6.635	-.000371	.006410	.004536
15.518	1.686	6.631	.005795	.015496	-.001257
15.510	1.684	6.631	.003962	.011582	-.003051
15.501	1.684	6.629	.001128	.008668	-.006844
15.490	1.683	6.625	-.003705	.002755	-.012638
15.478	1.679	6.628	-.009538	-.007159	-.011431
15.468	1.677	6.631	-.013372	-.013073	-.010224
15.474	1.671	6.642	-.001205	-.006987	-.001018
15.474	1.668	6.657	.004961	-.003901	.012189
15.469	1.649	6.641	.006128	-.021815	-.005605
15.459	1.651	6.629	.002295	-.023728	-.019398
15.441	1.671	6.622	-.009539	-.015642	-.028191
15.437	1.679	6.619	-.007372	-.005556	-.032985
15.448	1.685	6.611	.009794	.017530	-.042778
15.451	1.674	6.617	.018961	.015616	-.038572
15.439	1.682	6.631	.013128	.017702	-.026365
15.445	1.678	6.653	.025294	.025788	-.006158
15.446	1.684	6.665	.032461	.038875	.004048
15.437	1.692	6.672	.029627	.043961	.009255
15.418	1.689	6.672	.016794	.028047	.007462
15.401	1.688	6.674	.005961	.016133	.007668
15.395	1.682	6.681	.006127	.010219	.012875
15.399	1.672	6.672	.016294	.010305	.002081
15.388	1.672	6.673	.011460	.005392	.001288
15.381	1.682	6.668	.010627	.014478	-.005505
15.374	1.652	6.668	.009794	-.016436	-.007299
15.360	1.655	6.696	.001960	-.021350	.018908
15.347	1.678	6.686	-.004873	-.005264	.007114
15.324	1.679	6.688	-.021706	-.021178	.007321
15.331	1.676	6.709	-.008540	-.011092	.026528
15.330	1.679	6.733	-.003373	-.003005	.048734
15.320	1.674	6.745	-.007207	-.011919	.058941
15.308	1.690	6.720	-.013040	-.001833	.032147
15.301	1.693	6.688	-.013873	.000253	-.001646
15.298	1.686	6.678	-.010707	-.003661	-.013439
15.289	1.681	6.662	-.013540	-.011575	-.031233
15.289	1.679	6.663	-.007374	-.007488	-.032026
15.275	1.679	6.676	-.015207	-.015402	-.020820
15.284	1.662	6.695	-.000040	-.017316	-.003613
15.283	1.672	6.700	.005126	-.002230	-.000406
15.269	1.676	6.714	-.002707	-.006144	.011800
15.268	1.688	6.716	.002459	.010942	.012007
15.252	1.685	6.706	-.007374	-.001972	.000213
15.255	1.695	6.690	.001793	.017115	-.017580

TRACK STATION 28000

RAW DATA			DATA WITH LINE REMOVED		
TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL	TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL
11.132	1.671	6.665	.012597	.007745	.017411
11.121	1.684	6.662	.010420	.018496	.013885
11.108	1.685	6.657	.006244	.015246	.008359
11.100	1.686	6.651	.007067	.016997	.001832
11.087	1.679	6.652	.002890	.005747	.002306
11.079	1.678	6.647	.003713	.005498	-.003220
11.070	1.678	6.649	.003536	.005249	-.001746
11.058	1.678	6.645	.000359	.001999	-.006273
11.047	1.686	6.646	-.001817	.007750	-.005799
11.036	1.683	6.645	-.003994	.002500	-.007325
11.028	1.685	6.645	-.003171	.005251	-.007851
11.018	1.679	6.641	-.004348	-.001998	-.012378
11.008	1.680	6.650	-.005525	-.002248	-.003904
10.993	1.678	6.649	-.011702	-.010497	-.005430
10.983	1.675	6.657	-.012878	-.014747	.002044
10.980	1.685	6.663	-.007055	.001004	.007517
10.964	1.684	6.663	-.014232	-.007245	.006991
10.9641	1.672	6.657	-.005409	-.010495	.000465
10.964	1.670	6.656	.003414	-.003744	-.001061
10.960	1.674	6.653	.008237	.005006	-.004588
10.942	1.673	6.651	-.000939	-.005243	-.007114
10.933	1.660	6.664	-.001116	-.018493	.005360
10.922	1.655	6.660	-.003293	-.025742	.000834
10.922	1.671	6.660	.005530	-.000991	.000307
10.910	1.672	6.662	.002353	-.003241	.001781
10.893	1.669	6.664	-.005824	-.014490	.003255
10.893	1.650	6.658	.003000	-.024740	-.003271
10.893	1.668	6.664	.011823	.002011	.002202
10.870	1.675	6.664	-.002354	-.005238	.001676
10.870	1.672	6.663	.006469	.000512	.000150
10.859	1.678	6.662	.004292	.004263	-.001376
10.846	1.683	6.666	.000115	.005013	.002097
10.820	1.688	6.665	-.017061	-.007236	.000571
10.806	1.679	6.669	-.022238	-.021485	.004045
10.805	1.678	6.666	-.014415	-.014735	.000519
10.805	1.664	6.654	-.005592	-.019984	-.012008
10.809	1.668	6.648	.007231	-.003234	-.018534
10.783	1.677	6.662	-.009946	-.011483	-.005060
10.781	1.675	6.664	-.003122	-.006733	-.003586
10.781	1.686	6.669	.005701	.013018	.000887
10.785	1.685	6.673	.018524	.024769	.004361
10.780	1.697	6.671	.022347	.040519	.001835
10.763	1.689	6.667	.014170	.024270	-.002691
10.740	1.677	6.659	-.000007	-.001980	-.011217
10.736	1.678	6.660	.004817	.003771	-.010744
10.721	1.675	6.667	-.001360	-.005478	-.004270
10.708	1.686	6.677	-.005537	.001272	.005204
10.708	1.681	6.682	.003286	.005023	.009678
10.705	1.685	6.681	.009109	.014773	.008151
10.678	1.687	6.682	-.009068	-.001476	.008625
10.673	1.690	6.691	-.005244	.005275	.017099

TRACK STATION 30000

RAW DATA			DATA WITH LINE REMOVED		
TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL	TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL
13.322	1.688	6.632	-.012011	.023192	-.005551
13.328	1.671	6.631	.002843	.020625	-.007168
13.331	1.662	6.637	.014698	.023057	-.001785
13.309	1.680	6.647	.001552	.027489	.007598
13.290	1.672	6.652	-.008593	.008922	.011981
13.278	1.655	6.652	-.011738	-.011646	.011363
13.272	1.628	6.637	-.008884	-.036214	-.004254
13.267	1.633	6.640	-.005029	-.027782	-.001871
13.253	1.630	6.644	-.010175	-.036349	.001512
13.250	1.625	6.639	-.004320	-.035917	-.004105
13.249	1.625	6.642	.003534	-.028485	-.001722
13.248	1.623	6.647	.011389	-.023052	.002660
13.232	1.639	6.643	.004244	-.014620	-.001957
13.210	1.674	6.639	-.008902	.006812	-.006574
13.223	1.689	6.635	.012953	.043245	-.011191
13.219	1.685	6.638	.017807	.043677	-.008808
13.204	1.677	6.646	.011662	.029109	-.001426
13.190	1.664	6.644	.006516	.010542	-.004043
13.169	1.655	6.647	-.005629	-.011026	-.001660
13.177	1.641	6.638	.011226	-.008594	-.011277
13.151	1.625	6.650	-.005920	-.042162	.000106
13.144	1.651	6.656	-.004065	-.014729	.005488
13.133	1.674	6.676	-.006211	.005703	.024871
13.139	1.672	6.672	.008644	.018135	.020254
13.123	1.689	6.661	.001498	.027568	.008637
13.114	1.679	6.670	.001353	.017000	.017020
13.100	1.673	6.656	-.003792	.005432	.002402
13.104	1.671	6.646	.009062	.015865	-.008215
13.095	1.685	6.642	.008917	.029297	-.012832
13.092	1.678	6.654	.014771	.027729	-.001449
13.071	1.677	6.664	.002626	.014162	.007934
13.021	1.658	6.659	-.038520	-.046406	.002316
13.043	1.650	6.655	-.007665	-.023974	-.002301
13.029	1.653	6.659	-.012810	-.026542	.001082
13.022	1.649	6.652	-.010956	-.029109	-.006535
13.015	1.649	6.653	-.009101	-.027677	-.006152
13.000	1.643	6.647	-.015247	-.040245	-.012770
13.004	1.660	6.641	-.002392	-.010812	-.019387
13.005	1.686	6.645	.007462	.024620	-.016004
12.995	1.693	6.648	.006317	.030052	-.013621
13.003	1.663	6.667	.023171	.016485	.004762
12.997	1.677	6.682	.026026	.032917	.019144
12.974	1.679	6.674	.011881	.020349	.010527
12.959	1.674	6.669	.005735	.008782	.004910
12.949	1.662	6.685	.004590	-.004786	.020293
12.922	1.646	6.668	-.013556	-.039354	.002676
12.921	1.679	6.662	-.005701	.001078	-.003941
12.909	1.680	6.658	-.008847	-.001489	-.008559
12.908	1.685	6.664	-.000992	.010943	-.003176
12.894	1.687	6.666	-.006137	.007375	-.001793
12.888	1.668	6.671	-.003283	-.009192	.002590

TRACK STATION 32000

RAW DATA			DATA WITH LINE REMOVED		
TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL	TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL
10.030	1.681	6.645	-.001556	.007712	.010299
10.016	1.671	6.644	-.010490	-.011288	.009790
10.018	1.655	6.636	-.003423	-.020287	.002282
10.012	1.636	6.636	-.004357	-.040286	.002773
10.013	1.648	6.642	.001709	-.022286	.009265
10.000	1.652	6.636	-.006225	-.026285	.003757
9.989	1.676	6.624	-.012159	-.008285	-.007752
9.995	1.682	6.621	-.001093	.008716	-.010260
9.996	1.682	6.623	.004973	.014716	-.007769
9.991	1.690	6.635	.005040	.022717	.004723
9.982	1.687	6.631	.001106	.015717	.001214
9.974	1.679	6.614	-.001828	.004718	-.015294
9.965	1.667	6.613	-.005762	-.011282	-.015802
9.966	1.672	6.621	.000304	-.000281	-.007311
9.956	1.678	6.640	-.004630	.000720	.012181
9.968	1.682	6.640	.012437	.021720	.012672
9.950	1.689	6.631	-.000497	.015721	.004164
9.940	1.670	6.623	-.005431	-.008279	-.003344
9.936	1.667	6.613	-.004365	-.010278	-.012853
9.940	1.675	6.624	.004701	.006722	-.001361
9.929	1.678	6.616	-.001233	.003723	-.008870
9.922	1.689	6.616	-.003167	.012723	-.008378
9.922	1.676	6.624	.001900	.004724	.000113
9.916	1.663	6.621	.000966	-.009276	-.002395
9.913	1.676	6.618	.003032	.005725	-.004903
9.908	1.685	6.606	.003098	.014725	-.016412
9.905	1.684	6.607	.005164	.015726	-.014920
9.908	1.679	6.615	.013230	.018727	-.006429
9.908	1.684	6.625	.018297	.028727	.004063
9.900	1.683	6.636	.015363	.024728	.015555
9.882	1.688	6.636	.002429	.016728	.016046
9.885	1.677	6.628	.010495	.013729	.008538
9.867	1.681	6.624	-.002439	.004729	.005029
9.862	1.669	6.624	-.002373	-.007270	.005521
9.855	1.666	6.639	-.004307	-.012270	.021012
9.857	1.669	6.635	.002760	-.002269	.017504
9.855	1.646	6.620	.005826	-.022269	.002996
9.854	1.664	6.615	.009892	-.000268	-.001513
9.838	1.671	6.612	-.001042	-.004267	-.004021
9.839	1.671	6.608	.005024	.001733	-.007530
9.834	1.678	6.612	.005090	.008734	-.003038
9.818	1.669	6.624	-.005843	-.011266	.009454
9.812	1.665	6.620	-.006777	-.016265	.005945
9.824	1.668	6.618	.010289	.003735	.004437
9.802	1.661	6.615	-.006645	-.020264	.001928
9.790	1.661	6.610	-.013579	-.027264	-.002580
9.793	1.673	6.606	-.005513	-.007263	-.006089
9.782	1.669	6.610	-.011447	-.017263	-.001597
9.785	1.686	6.605	-.003380	.007738	-.006105
9.774	1.690	6.605	-.009314	.005739	-.005614
9.774	1.684	6.601	-.004248	.004739	-.009122

TRACK STATION 34000

RAW DATA | DATA WITH LINE REMOVED

TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL	TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL
15.106	1.676	6.546	.014668	.011833	-.012351
15.106	1.675	6.561	.020669	.016950	.003454
15.096	1.661	6.575	.016670	-.000933	.018259
15.088	1.641	6.566	.014670	-.022816	.010063
15.076	1.673	6.561	.008671	.003302	.005868
15.067	1.684	6.559	.005672	.011419	.004672
15.064	1.677	6.560	.008673	.007536	.006477
15.053	1.680	6.554	.003673	.005654	.001282
15.045	1.675	6.553	.001674	-.001229	.001086
15.050	1.678	6.550	.012675	.012888	-.001109
15.045	1.689	6.545	.013675	.025005	-.005305
15.038	1.684	6.536	.012676	.019123	-.013500
15.026	1.685	6.545	.006677	.014240	-.003695
15.026	1.679	6.549	.012678	.014357	.001109
15.022	1.682	6.556	.014678	.019475	.008914
15.015	1.681	6.556	.013679	.017592	.009719
15.000	1.682	6.546	.004680	.009709	.000523
14.982	1.684	6.546	-.007320	-.000174	.001328
14.973	1.672	6.543	-.010319	-.015056	-.000868
14.956	1.675	6.533	-.021318	-.022939	-.010063
14.950	1.682	6.533	-.021317	-.015822	-.009258
14.945	1.680	6.528	-.020317	-.016704	-.013454
14.949	1.679	6.528	-.010316	-.007587	-.012649
14.952	1.681	6.535	-.001315	.003530	-.004845
14.941	1.688	6.540	-.006314	.005647	.000960
14.929	1.687	6.544	-.012314	-.001235	.005765
14.911	1.679	6.537	-.024313	-.021118	-.000431
14.869	1.674	6.528	-.060312	-.062001	-.008626
14.899	1.677	6.529	-.024312	-.022883	-.006821
14.903	1.677	6.529	-.014311	-.012766	-.006017
14.908	1.686	6.528	-.003310	.007351	-.006212
14.902	1.684	6.538	-.003309	.005468	.004592
14.887	1.685	6.544	-.012309	-.002414	.011397
14.875	1.675	6.552	-.018308	-.018297	.020202
14.858	1.681	6.542	-.029307	-.023180	.011006
14.851	1.668	6.531	-.030306	-.037062	.000811
14.832	1.667	6.523	-.043306	-.050945	-.006385
14.844	1.673	6.515	-.025305	-.026828	-.013580
14.844	1.674	6.515	-.019304	-.019711	-.012775
14.853	1.673	6.516	-.004304	-.005593	-.010971
14.844	1.676	6.519	-.007303	-.005476	-.007166
14.848	1.666	6.520	.002698	-.005359	-.005361
14.853	1.663	6.520	.013699	.002759	-.004557
14.859	1.671	6.529	.025699	.022876	.005248
14.859	1.677	6.532	.031700	.034993	.009052
14.864	1.677	6.532	.042701	.046110	.009857
14.846	1.676	6.530	.030701	.033228	.008662
14.832	1.670	6.528	.022702	.019345	.007466
14.830	1.667	6.519	.026703	.020462	-.000729
14.822	1.663	6.522	.024704	.014580	.003075
14.814	1.663	6.524	.022704	.012697	.005880

TRACK STATION 36000

RAW DATA | DATA WITH LINE REMOVED

TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL	TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL
12.432	1.709	6.815	.039090	.037211	-.015709
12.417	1.707	6.818	.033765	.029870	-.013927
12.394	1.703	6.840	.020439	.012529	.006855
12.367	1.709	6.830	.003114	.001188	-.004363
12.344	1.710	6.831	-.010211	-.011153	-.004581
12.340	1.720	6.884	-.004536	.004506	.047202
12.330	1.712	6.840	-.004861	-.003835	.001984
12.318	1.709	6.848	-.007186	-.009176	.008766
12.302	1.710	6.860	-.013512	-.014517	.019548
12.295	1.708	6.859	-.010837	-.013858	.017330
12.281	1.708	6.865	-.015162	-.018199	.022112
12.287	1.712	6.871	.000513	.001460	.026894
12.277	1.716	6.850	.000188	.005119	.004676
12.266	1.713	6.830	-.001137	.000778	-.016542
12.266	1.715	6.839	.008538	.012437	-.008760
12.244	1.720	6.848	-.003788	.005096	-.000978
12.220	1.718	6.856	-.018113	-.011245	.005804
12.220	1.716	6.857	-.008438	-.003586	.005586
12.220	1.714	6.856	.001237	.004073	.003369
12.200	1.711	6.847	-.009088	-.009268	-.006849
12.200	1.709	6.834	.000587	-.001609	-.021067
12.190	1.703	6.832	.000261	-.007950	-.024285
12.172	1.708	6.838	-.008064	-.011291	-.019503
12.172	1.710	6.837	.001611	.000368	-.021721
12.162	1.712	6.836	.001286	.002027	-.023939
12.152	1.710	6.836	.000961	-.000314	-.025157
12.140	1.711	6.837	-.001364	-.001655	-.025375
12.132	1.709	6.864	.000310	-.001996	.000407
12.117	1.705	6.870	-.005015	-.011337	.005189
12.093	1.709	6.872	-.019340	-.021678	.005971
12.087	1.712	6.872	-.015665	-.015019	.004754
12.079	1.717	6.861	-.013990	-.008360	-.007464
12.079	1.713	6.867	-.004315	-.002701	-.002682
12.022	1.712	6.867	-.051640	-.051042	-.003900
12.068	1.708	6.872	.004034	.000617	-.000118
12.057	1.710	6.885	.002709	.001276	.011664
12.065	1.713	6.887	.020384	.021935	.012446
12.056	1.715	6.889	.021059	.024594	.013228
12.043	1.717	6.884	.017734	.023253	.007010
12.040	1.712	6.883	.024409	.024912	.004792
12.021	1.710	6.880	.015083	.013571	.000574
11.983	1.708	6.860	-.013242	-.016770	-.020644
11.983	1.712	6.861	-.003567	-.003111	-.020861
11.972	1.712	6.859	-.004892	-.004452	-.024079
11.969	1.714	6.871	.001783	.004207	-.013297
11.969	1.712	6.900	.011458	.011866	.014485
11.954	1.713	6.909	.006132	.007525	.022267
11.938	1.707	6.896	-.000193	-.004816	.008049
11.938	1.708	6.886	.009482	.005843	-.003169
11.925	1.711	6.900	.006157	.005502	.009613
11.905	1.713	6.930	-.004168	-.002839	.038395

TRACK STATION 38000

RAW DATA			DATA WITH LINE REMOVED		
TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL	TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL
12.399	1.677	6.882	.002651	-.006440	-.009966
12.386	1.658	6.880	-.001043	-.029381	-.012050
12.371	1.634	6.882	-.006736	-.059322	-.010133
12.357	1.668	6.882	-.011430	-.030263	-.010217
12.356	1.688	6.900	-.003123	-.002204	.007699
12.358	1.694	6.901	.008183	.014856	.008615
12.357	1.698	6.890	.016490	.026915	-.002468
12.347	1.701	6.881	.015796	.028974	-.011552
12.331	1.702	6.905	.009103	.023033	.012364
12.311	1.698	6.915	-.001591	.008092	.022281
12.305	1.697	6.913	.001716	.010151	.020197
12.307	1.691	6.898	.013023	.015211	.005113
12.292	1.699	6.883	.007329	.017270	-.009971
12.287	1.701	6.881	.011636	.023329	-.012054
12.278	1.698	6.882	.011942	.020388	-.011138
12.251	1.702	6.900	-.005751	.006447	.006778
12.243	1.698	6.901	-.004445	.003507	.007695
12.243	1.692	6.901	.004862	.006566	.007611
12.228	1.692	6.895	-.000832	.000625	.001527
12.221	1.695	6.894	.001475	.005684	.000443
12.217	1.697	6.896	.006781	.012743	.002360
12.205	1.670	6.895	.004088	-.017198	.001276
12.177	1.695	6.885	-.014606	-.011138	-.008808
12.172	1.698	6.886	-.010299	-.004079	-.007891
12.157	1.697	6.900	-.015993	-.011020	.006025
12.159	1.697	6.900	-.004686	.000039	.005941
12.132	1.696	6.906	-.022380	-.018902	.011857
12.126	1.699	6.906	-.019073	-.012842	.011774
12.125	1.702	6.914	-.010767	-.001783	.019690
12.119	1.700	6.910	-.007460	-.000724	.015606
12.115	1.696	6.909	-.002154	.000335	.014523
12.096	1.689	6.905	-.011847	-.016606	.010439
12.080	1.696	6.905	-.018541	-.016546	.010355
12.066	1.699	6.893	-.023234	-.018487	-.001729
12.066	1.696	6.870	-.013928	-.012428	-.024812
12.061	1.700	6.851	-.009621	-.004369	-.043896
12.064	1.697	6.848	.002685	.004690	-.046980
12.048	1.693	6.848	-.004008	-.006251	-.047063
12.055	1.688	6.876	.012298	.004809	-.019147
12.029	1.688	6.908	-.004395	-.012132	.012769
12.035	1.694	6.927	.010911	.008927	.031686
12.049	1.692	6.927	.034218	.029986	.031602
12.035	1.691	6.907	.029524	.024045	.011518
12.007	1.689	6.878	.010831	.003105	-.017566
11.985	1.694	6.870	-.001862	-.004836	-.025649
11.991	1.694	6.873	.013444	.010223	-.022733
11.983	1.697	6.894	.014751	.014282	-.001817
11.963	1.696	6.914	.004057	.002341	.018100
11.942	1.695	6.910	-.007636	-.010600	.014016
11.936	1.693	6.909	-.004330	-.009540	.012932
11.925	1.695	6.911	-.006023	-.009481	.014848

TRACK STATION 40000

RAW DATA			DATA WITH LINE REMOVED		
TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL	TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL
14.520	1.696	6.873	.023925	.017957	.000037
14.495	1.695	6.876	.014578	.007260	.001729
14.464	1.696	6.859	-.000769	-.007437	-.016579
14.440	1.696	6.857	-.009116	-.016134	-.019887
14.422	1.695	6.860	-.011463	-.019831	-.018196
14.408	1.690	6.860	-.009809	-.023529	-.019504
14.410	1.689	6.868	.007844	-.007226	-.012812
14.393	1.699	6.865	.006497	.001077	-.017120
14.360	1.687	6.867	-.010850	-.028620	-.016428
14.339	1.713	6.867	-.016197	-.008317	-.017736
14.340	1.720	6.888	.000457	.014986	.001956
14.330	1.720	6.900	.006110	.020289	.012647
14.317	1.717	6.906	.008763	.019592	.017339
14.298	1.708	6.922	.005416	.006895	.032031
14.275	1.708	6.914	-.001930	-.000802	.022723
14.250	1.710	6.898	-.011277	-.008500	.005415
14.230	1.713	6.894	-.015624	-.010197	.000107
14.191	1.710	6.885	-.038971	-.036894	-.010202
14.200	1.714	6.885	-.014318	-.008591	-.011510
14.208	1.714	6.878	.009336	.014712	-.019818
14.205	1.712	6.890	.021989	.025015	-.009126
14.192	1.713	6.904	.024642	.028318	.003566
14.159	1.715	6.908	.007295	.012621	.006258
14.142	1.720	6.908	.005948	.015924	.004950
14.120	1.719	6.917	-.000398	.008227	.012641
14.110	1.716	6.917	.005255	.010529	.011333
14.100	1.717	6.916	.010908	.016832	.009025
14.090	1.715	6.923	.016561	.020135	.014717
14.087	1.716	6.940	.029215	.033438	.030409
14.060	1.714	6.954	.017868	.019741	.043101
14.029	1.717	6.948	.002521	.007044	.035793
14.008	1.713	6.939	-.002826	-.002653	.025484
13.970	1.713	6.925	-.025173	-.025350	.010176
13.940	1.711	6.920	-.039519	-.042047	.003868
13.945	1.714	6.923	-.018866	-.018745	.005560
13.945	1.718	6.929	-.003213	.000558	.010252
13.930	1.715	6.929	-.002560	-.002139	.008944
13.915	1.720	6.929	-.001907	.003164	.007636
13.887	1.709	6.921	-.014253	-.020533	-.001673
13.882	1.720	6.921	-.003600	.000770	-.002981
13.873	1.713	6.921	.003053	.000073	-.004289
13.852	1.715	6.927	-.002294	-.003624	.000403
13.830	1.716	6.916	-.008640	-.009321	-.011905
13.800	1.717	6.902	-.022987	-.023018	-.027213
13.798	1.715	6.900	-.009334	-.011716	-.030521
13.795	1.713	6.911	.003319	-.001413	-.020830
13.787	1.701	6.927	.010972	-.006110	-.006138
13.780	1.706	6.905	.019626	.007193	-.029446
13.775	1.718	6.912	.030279	.029496	-.023754
13.733	1.720	6.935	.003932	.004799	-.002062
13.713	1.716	6.950	-.000415	-.003898	.011630

TRACK STATION 42000

RAW DATA			DATA WITH LINE REMOVED		
TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL	TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL
10.552	1.706	6.883	-.020791	-.025801	-.025564
10.548	1.715	6.905	-.014137	-.011145	-.003903
10.558	1.713	6.903	.006518	.006510	-.006242
10.552	1.715	6.886	.011172	.012166	-.023581
10.542	1.721	6.898	.011826	.017821	-.011920
10.519	1.718	6.912	-.000519	.001477	.001741
10.509	1.720	6.918	.000135	.003132	.007402
10.515	1.719	6.913	.016790	.017788	.002063
10.512	1.729	6.919	.024444	.034444	.007724
10.509	1.746	6.928	.032098	.058099	.016385
10.500	1.756	6.917	.033753	.068755	.005046
10.474	1.761	6.908	.018407	.057410	-.004293
10.443	1.730	6.902	-.001938	.005066	-.010632
10.412	1.735	6.904	-.022284	-.011279	-.008971
10.410	1.741	6.905	-.013630	.002377	-.008310
10.407	1.720	6.918	-.005975	-.011967	.004351
10.401	1.715	6.926	-.001321	-.013312	.012012
10.384	1.720	6.923	-.007666	-.015656	.008673
10.361	1.716	6.917	-.020012	-.033001	.002334
10.347	1.712	6.916	-.023358	-.041345	.000995
10.344	1.721	6.919	-.015703	-.025690	.003656
10.345	1.717	6.902	-.004049	-.019034	-.013683
10.342	1.711	6.902	.003605	-.018378	-.014022
10.332	1.712	6.892	.004260	-.017723	-.024361
10.320	1.711	6.896	.002914	-.021067	-.020700
10.306	1.714	6.925	-.000431	-.022412	.007961
10.287	1.721	6.916	-.008777	-.024756	-.001378
10.262	1.721	6.902	-.023123	-.040101	-.015717
10.262	1.720	6.910	-.012468	-.031445	-.008056
10.263	1.713	6.919	-.000814	-.027790	.000605
10.241	1.738	6.965	-.012159	-.015134	.046266
10.212	1.730	6.968	-.030505	-.042478	.048927
10.216	1.727	6.943	-.015851	-.031823	.023588
10.229	1.730	6.917	.007804	-.006167	-.002751
10.223	1.763	6.936	.012458	.030488	.015910
10.192	1.775	6.954	-.007887	.021144	.033571
10.183	1.775	6.948	-.006233	.021799	.027232
10.171	1.778	6.944	-.007579	.022455	.022893
10.156	1.779	6.930	-.011924	.018111	.008554
10.172	1.804	6.941	.014730	.068766	.019215
10.182	1.731	6.950	.035384	.015422	.027876
10.170	1.725	6.949	.034039	.007077	.026537
10.144	1.715	6.932	.018693	-.019267	.009198
10.116	1.722	6.921	.001348	-.030612	-.002141
10.112	1.720	6.925	.008002	-.026956	.001520
10.102	1.763	6.917	.008656	.015700	-.006819
10.086	1.761	6.910	.003311	.007355	-.014158
10.069	1.774	6.881	-.003035	.013011	-.043497
10.055	1.743	6.881	-.006380	-.022334	-.043836
10.047	1.811	6.886	-.003726	.047322	-.039175
10.032	1.802	6.887	-.008072	.032977	-.038514

TRACK STATION 44000

RAW DATA			DATA WITH LINE REMOVED		
TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL	TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL
13.017	1.711	6.923	-.012127	-.013754	-.012826
13.013	1.716	6.923	-.006020	-.002653	-.012988
13.008	1.713	6.920	-.000913	-.000551	-.016150
13.003	1.712	6.927	.004194	.003550	-.009313
12.992	1.707	6.920	.003301	-.002348	-.016475
12.970	1.708	6.940	-.008592	-.013246	.003363
12.968	1.712	6.943	-.000485	-.001145	.006201
12.960	1.716	6.946	.001622	.004957	.009038
12.960	1.713	6.945	.011729	.012058	.007876
12.933	1.713	6.945	-.005164	-.004840	.007714
12.920	1.709	6.945	-.008057	-.011739	.007552
12.914	1.709	6.968	-.003950	-.007637	.030389
12.918	1.713	6.974	.010157	.010464	.036227
12.895	1.712	6.952	-.002736	-.003434	.014065
12.890	1.715	6.940	.002371	.004667	.001903
12.890	1.715	6.940	.012478	.014769	.001740
12.876	1.715	6.949	.008585	.010870	.010578
12.874	1.714	6.949	.016693	.017972	.010416
12.865	1.709	6.958	.017800	.014074	.019253
12.841	1.716	6.939	.003907	.007175	.000091
12.826	1.721	6.931	-.000986	.007277	-.008071
12.806	1.716	6.932	-.010879	-.007622	-.007233
12.806	1.715	6.926	-.000772	.001480	-.013396
12.784	1.709	6.926	-.012665	-.016419	-.013558
12.776	1.710	6.922	-.010558	-.013317	-.017720
12.768	1.709	6.922	-.008451	-.012216	-.017882
12.760	1.709	6.931	-.006344	-.010114	-.009045
12.750	1.717	6.935	-.006237	-.002013	-.005207
12.737	1.713	6.932	-.009130	-.008911	-.008369
12.732	1.712	6.944	-.004023	-.004810	.003469
12.728	1.710	6.944	.002084	-.000708	.003306
12.722	1.713	6.948	.006191	.006394	.007144
12.715	1.714	6.934	.009298	.010495	-.007018
12.715	1.719	6.940	.019405	.025597	-.001180
12.693	1.717	6.943	.007513	.011698	.001657
12.675	1.711	6.934	-.000380	-.002200	-.007505
12.655	1.712	6.929	-.010273	-.011099	-.012667
12.655	1.710	6.928	-.000166	-.002997	-.013830
12.648	1.714	6.935	.002941	.004104	-.006992
12.638	1.716	6.935	.003048	.006206	-.007154
12.635	1.720	6.941	.010155	.017307	-.001316
12.618	1.713	6.946	.003262	.003409	.003521
12.599	1.715	6.946	-.005631	-.003490	.003359
12.591	1.709	6.942	-.003524	-.007388	-.000803
12.573	1.710	6.938	-.011417	-.014286	-.004965
12.550	1.713	6.936	-.024310	-.024185	-.007128
12.562	1.713	6.952	-.002203	-.002083	.008710
12.552	1.717	6.952	-.002096	.002018	.008548
12.544	1.710	6.948	.000011	-.002880	.004386
12.549	1.709	6.952	.015118	.011221	.008223
12.530	1.707	6.964	.006225	.000323	.020061

TRACK STATION 46000

RAW DATA			DATA WITH LINE REMOVED		
TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL	TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL
.666	1.703	6.922	-.046149	-.052403	-.026716
.694	1.705	6.934	-.017285	-.021570	-.015002
.698	1.708	6.921	-.012420	-.013737	-.028287
.709	1.711	6.914	-.000555	.001097	-.035572
.710	1.710	6.914	.001310	.001930	-.035857
.706	1.711	6.926	-.001825	-.000237	-.024142
.695	1.710	6.943	-.011961	-.011403	-.007427
.715	1.706	6.966	.008904	.005430	.015288
.709	1.709	6.980	.003769	.003264	.029003
.702	1.711	6.978	-.002366	-.000903	.026718
.690	1.712	6.987	-.013501	-.011070	.035433
.692	1.715	6.987	-.010637	-.005236	.035148
.705	1.707	7.009	.003228	.000597	.056863
.715	1.711	6.961	.014093	.015431	.008578
.707	1.721	6.948	.006958	.018264	-.004707
.685	1.717	6.936	-.014177	-.006903	-.016992
.690	1.718	6.936	-.008313	-.000069	-.017278
.689	1.710	6.942	-.008448	-.008236	-.011563
.690	1.710	6.950	-.006583	-.006402	-.003848
.699	1.711	6.950	.003282	.004431	-.004133
.717	1.709	6.943	.022147	.021264	-.011418
.709	1.716	6.961	.015011	.021098	.006297
.709	1.713	6.973	.015876	.018931	.018012
.701	1.709	6.958	.008741	.007765	.002727
.700	1.709	6.950	.008606	.007598	-.005558
.691	1.707	6.950	.000471	-.002569	-.005843
.677	1.714	6.941	-.012665	-.008735	-.015128
.671	1.706	6.941	-.017800	-.021902	-.015413
.686	1.682	6.937	-.001935	-.030068	-.019698
.695	1.686	6.937	.007930	-.016235	-.019983
.685	1.696	6.937	-.001205	-.015402	-.020268
.686	1.712	6.964	.000659	.002432	.006446
.700	1.714	6.990	.015524	.019265	.032161
.706	1.715	6.999	.022389	.027099	.040876
.714	1.718	6.999	.031254	.038932	.040591
.735	1.717	6.994	.053119	.059765	.035306
.740	1.716	6.981	.058983	.064599	.022021
.729	1.713	6.966	.048848	.051432	.006736
.713	1.707	6.978	.033713	.030265	.018451
.715	1.713	6.981	.036578	.039099	.021166
.707	1.712	6.979	.029443	.030932	.018881
.674	1.718	6.970	-.002693	.004766	.009596
.661	1.711	6.965	-.014828	-.014401	.004311
.657	1.711	6.971	-.017963	-.017568	.010026
.660	1.710	6.994	-.014098	-.014734	.032741
.653	1.703	6.984	-.020233	-.027901	.022456
.635	1.706	6.949	-.037369	-.042067	-.012830
.633	1.713	6.909	-.038504	-.036234	-.053115
.634	1.714	6.914	-.036639	-.033401	-.048400
.636	1.718	6.915	-.033774	-.026567	-.047685
.622	1.708	6.914	-.046910	-.049734	-.048970

TRACK STATION 48000

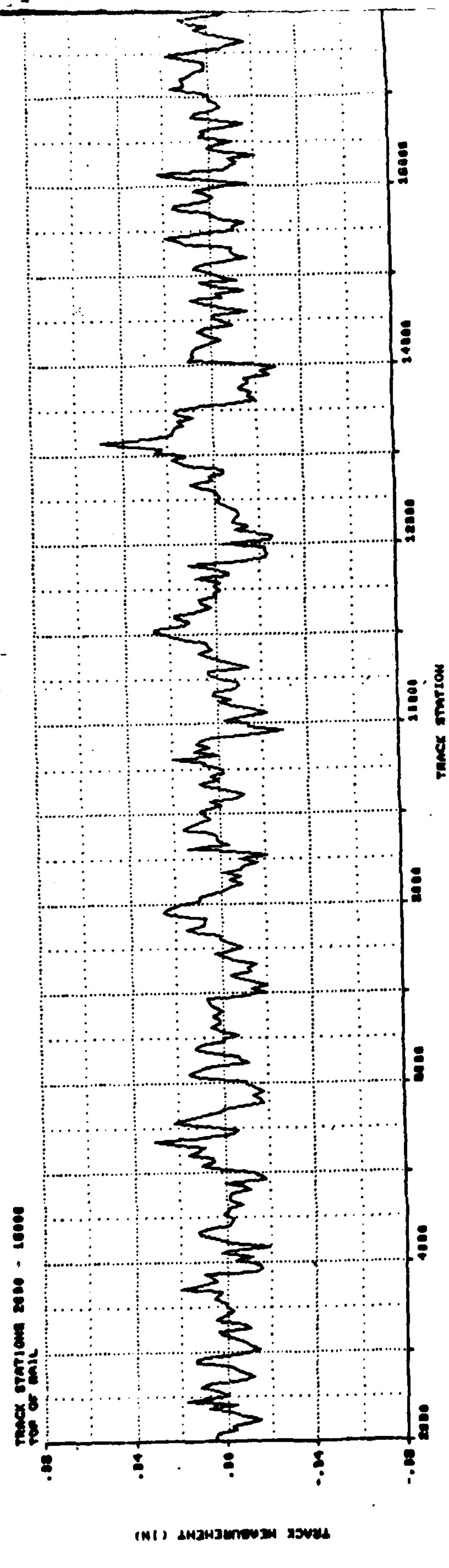
RAW DATA			DATA WITH LINE REMOVED		
TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL	TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL
10.983	1.701	7.175	-.017839	-.012320	.010408
10.989	1.700	7.180	-.010027	-.005485	.015676
10.981	1.698	7.185	-.016215	-.013650	.020943
10.982	1.696	7.185	-.013402	-.012816	.021211
10.982	1.697	7.190	-.011590	-.009981	.026478
10.990	1.694	7.190	-.001777	-.003146	.026746
11.005	1.698	7.210	.015035	.017689	.047014
11.000	1.678	7.215	.011847	-.005477	.052281
11.003	1.697	7.200	.016660	.018358	.037549
11.000	1.695	7.190	.015472	.015193	.027816
11.023	1.703	7.191	.040285	.048028	.029084
11.008	1.693	7.150	.027097	.024863	-.011648
11.004	1.697	7.175	.024909	.026697	.013619
11.000	1.696	7.177	.022722	.023532	.015887
10.975	1.692	7.160	-.000466	-.003633	-.000846
10.970	1.689	7.110	-.003653	-.009798	-.050578
10.975	1.695	7.105	.003159	.003036	-.055310
10.965	1.697	7.114	-.005029	-.003129	-.046043
10.948	1.696	7.124	-.020216	-.019294	-.035775
10.944	1.699	7.120	-.022404	-.018459	-.039508
10.932	1.708	7.120	-.032591	-.019625	-.039240
10.932	1.689	7.120	-.030779	-.036790	-.038972
10.944	1.693	7.135	-.016967	-.018955	-.023705
10.959	1.692	7.149	-.000154	-.003120	-.009437
10.965	1.695	7.155	.007658	.007714	-.003170
10.965	1.697	7.145	.009471	.011549	-.012902
10.965	1.694	7.140	.011283	.010384	-.017634
10.942	1.690	7.140	-.009905	-.014781	-.017367
10.952	1.689	7.141	.001908	-.003947	-.016099
10.965	1.688	7.134	.016720	.009888	-.022832
10.965	1.687	7.135	.018533	.010723	-.021564
10.954	1.697	7.125	.009345	.011558	-.031296
10.940	1.701	7.125	-.002843	.003392	-.031029
10.932	1.693	7.125	-.009030	-.010773	-.030761
10.930	1.694	7.125	-.009218	-.009938	-.030494
10.928	1.687	7.123	-.009405	-.017103	-.032226
10.920	1.698	7.133	-.015593	-.012269	-.021958
10.904	1.697	7.153	-.029781	-.027434	-.001691
10.912	1.698	7.165	-.019968	-.016599	.010577
10.918	1.696	7.170	-.012156	-.010764	.015844
10.921	1.696	7.170	-.007343	-.005930	.016112
10.931	1.694	7.168	.004469	.003905	.014380
10.940	1.692	7.160	.015281	.012740	.006647
10.951	1.693	7.170	.028094	.026575	.016915
10.951	1.696	7.185	.029906	.031409	.032182
10.912	1.697	7.195	-.007281	-.004756	.042450
10.912	1.689	7.219	-.005469	-.010921	.066718
10.911	1.697	7.216	-.004657	-.002086	.063985
10.910	1.705	7.194	-.003844	.006748	.042253
10.917	1.692	7.144	.004968	.002583	-.007480
10.925	1.696	7.128	.014781	.016418	-.023212

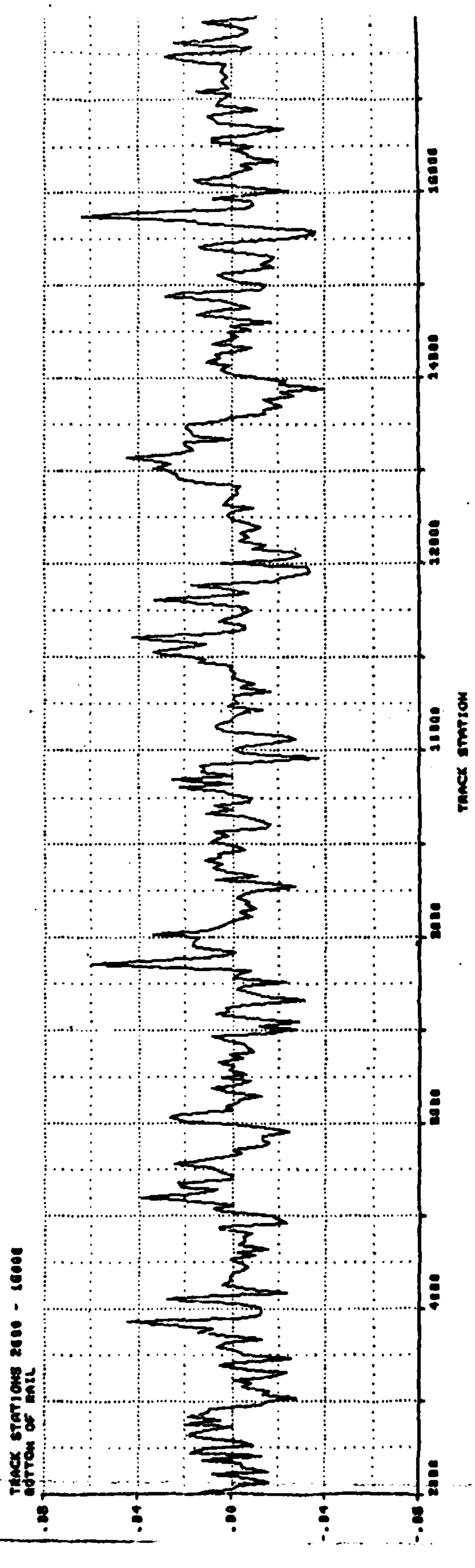
TRACK STATION 50000

RAW DATA			DATA WITH LINE REMOVED		
TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL	TOP OF RAIL	BOTTOM OF RAIL	SIDE OF RAIL
10.039	1.720	6.942	.019561	.026631	-.011043
10.041	1.718	6.925	.020972	.025999	-.028001
10.037	1.714	6.933	.016382	.017367	-.019960
10.014	1.713	6.958	-.007207	-.007266	.005082
9.991	1.708	6.975	-.030797	-.035898	.022124
9.990	1.712	6.951	-.032386	-.033530	-.001834
9.989	1.713	6.953	-.033976	-.034163	.000207
9.990	1.717	6.949	-.033565	-.029795	-.003751
10.019	1.703	6.960	-.005155	-.015427	.007291
10.059	1.715	6.941	.034256	.035940	-.011668
10.062	1.714	6.943	.036666	.037308	-.009626
10.039	1.715	6.957	.013077	.014676	.004416
10.035	1.706	6.965	.008487	.001044	.012458
10.037	1.714	6.972	.009898	.010411	.019499
10.030	1.716	6.963	.002308	.004779	.010541
10.023	1.717	6.958	-.005281	-.001853	.005583
10.022	1.713	6.955	-.006871	-.007486	.002625
10.007	1.709	6.952	-.022460	-.027118	-.000334
10.000	1.710	6.945	-.030050	-.033750	-.007292
10.011	1.710	6.958	-.019639	-.023383	.005750
10.031	1.715	6.943	-.000229	.000985	-.009209
10.038	1.714	6.942	.006182	.006353	-.010167
10.040	1.718	6.945	.007592	.011720	-.007125
10.037	1.716	6.934	.004003	.006088	-.018083
10.046	1.715	6.951	.012413	.013456	-.001042
10.057	1.714	6.962	.022824	.022824	.010000
10.064	1.710	6.968	.029234	.025191	.016042
10.058	1.712	6.967	.022645	.020559	.015083
10.045	1.715	6.951	.009055	.009927	-.000875
10.042	1.717	6.941	.005466	.008294	-.010833
10.047	1.716	6.950	.009876	.011662	-.001791
10.041	1.713	6.956	.003287	.002030	.004250
10.030	1.712	6.972	-.008303	-.010603	.020292
10.042	1.715	6.958	.003108	.003765	.006334
10.044	1.716	6.956	.004518	.006133	.004375
10.033	1.717	6.969	-.007071	-.004500	.017417
10.031	1.713	6.984	-.009661	-.011132	.032459
10.036	1.716	6.977	-.005250	-.003764	.025501
10.025	1.715	6.957	-.016840	-.016396	.005542
10.014	1.712	6.951	-.028430	-.031029	-.000416
10.021	1.715	6.943	-.022019	-.021661	-.008374
10.027	1.715	6.957	-.016609	-.016293	.005668
10.033	1.719	6.940	-.011198	-.006926	-.011291
10.056	1.719	6.917	.011212	.015442	-.034249
10.066	1.714	6.911	.020623	.019810	-.040207
10.053	1.710	6.923	.007033	.002177	-.028166
10.032	1.715	6.970	-.014556	-.014455	.018876
10.067	1.710	6.945	.019854	.014913	-.006082
10.065	1.716	6.950	.017265	.018280	-.001040
10.053	1.717	6.947	.004675	.006648	-.003999
10.034	1.716	6.960	-.014914	-.013984	.009043

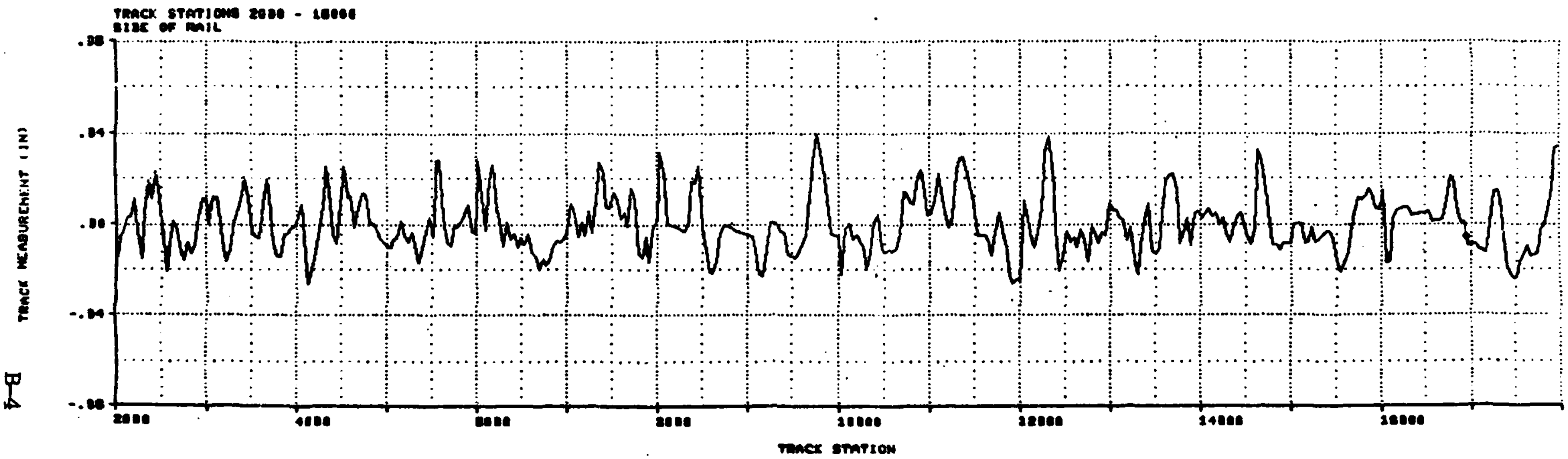
APPENDIX B

PLOTS OF ENSEMBLES RAW DATA


TRACK STATIONS 2000 - 18000
TOP OF RAIL
TRACK STATION
TRACK MEASUREMENT (IN)
.08
.04
.00
-.04
-.08
2000
4000
6000
8000
10000
12000
14000
16000



TRACK STATIONS 2000 - 18000
BOTTOM OF RAIL
.08
.04
.00
-.04
-.08
2000
4000
6000
8000
10000
12000
14000
16000
TRACK STATION
TRACK MEASUREMENT (IN)


TRACK STATIONS 2000 - 18000
SIDE OF RAIL
TRACK MEASUREMENT (IN)
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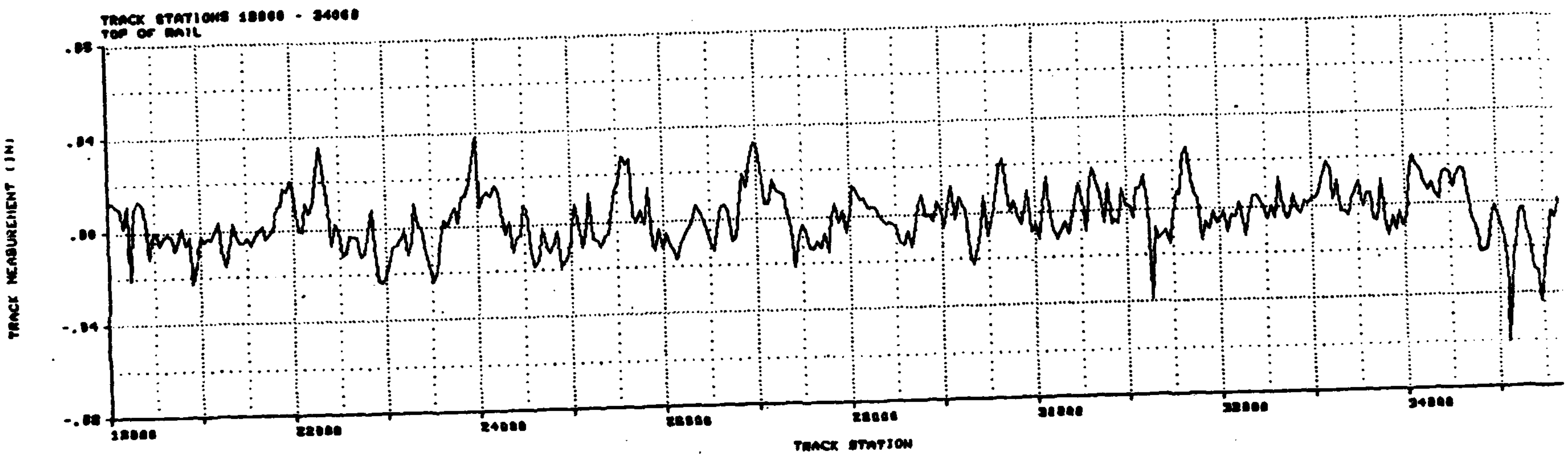
.04
.00
-.04
-.08
2000
4000
6000
8000
10000
12000
14000
16000
TRACK STATION


TRACK STATIONS 18000 - 34000
TOP OF RAIL
TRACK MEASUREMENT (IN)
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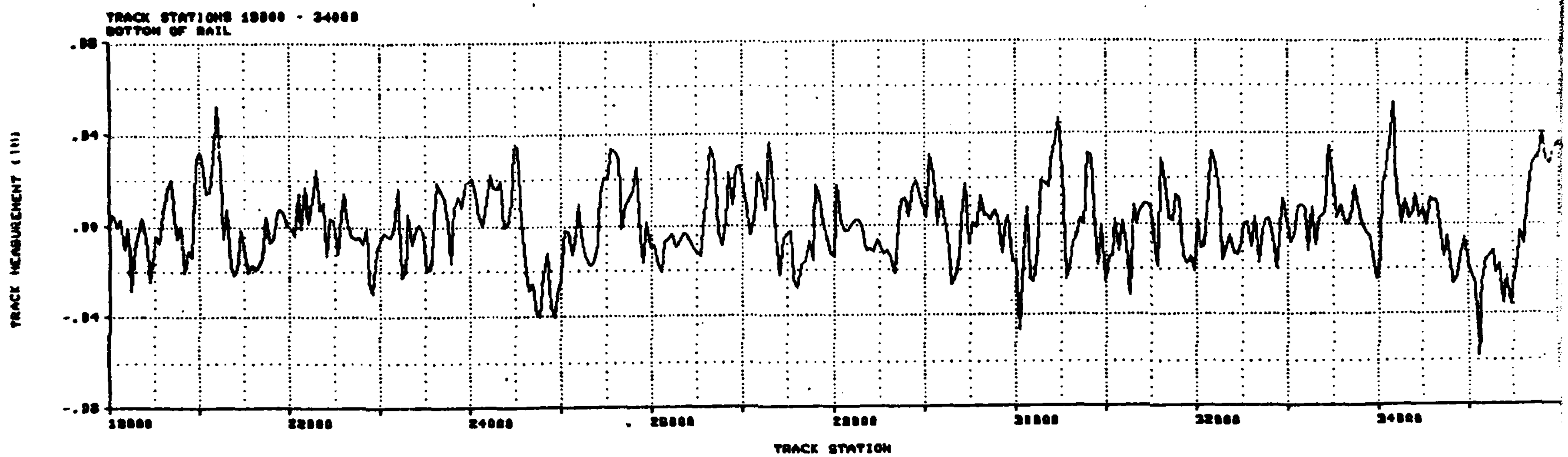
.00
-.04
-.08
22000
24000
34000
TRACK STATION


BOTTOM OF RAIL
TRACK MEASUREMENT (IN)
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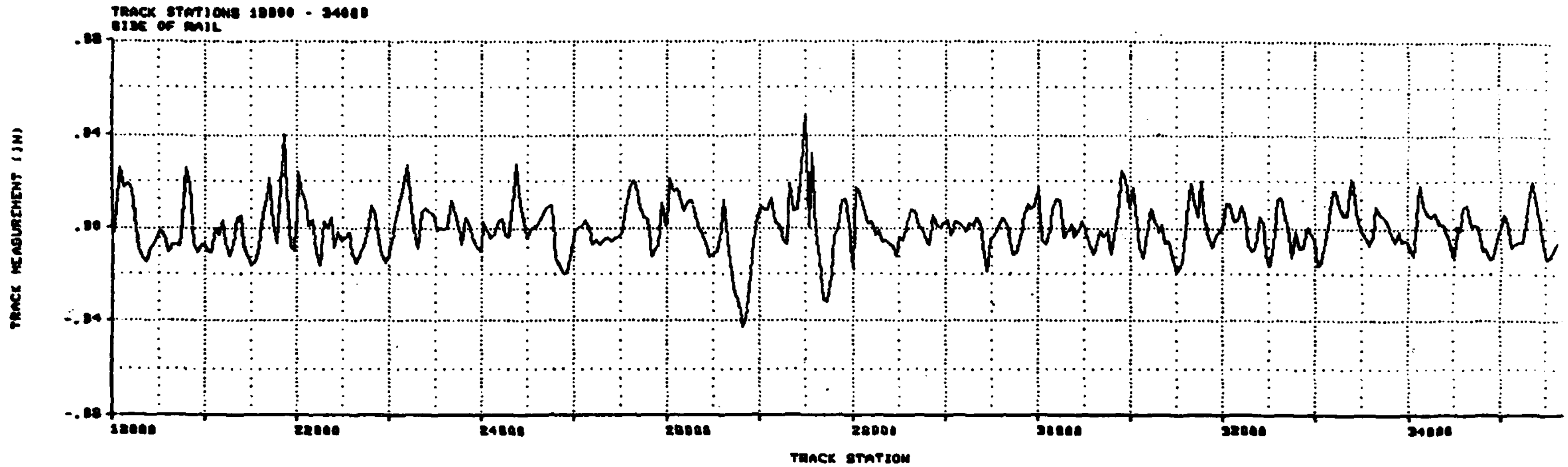
.00
-.04
24000
TRACK STATION


SIDE OF RAIL
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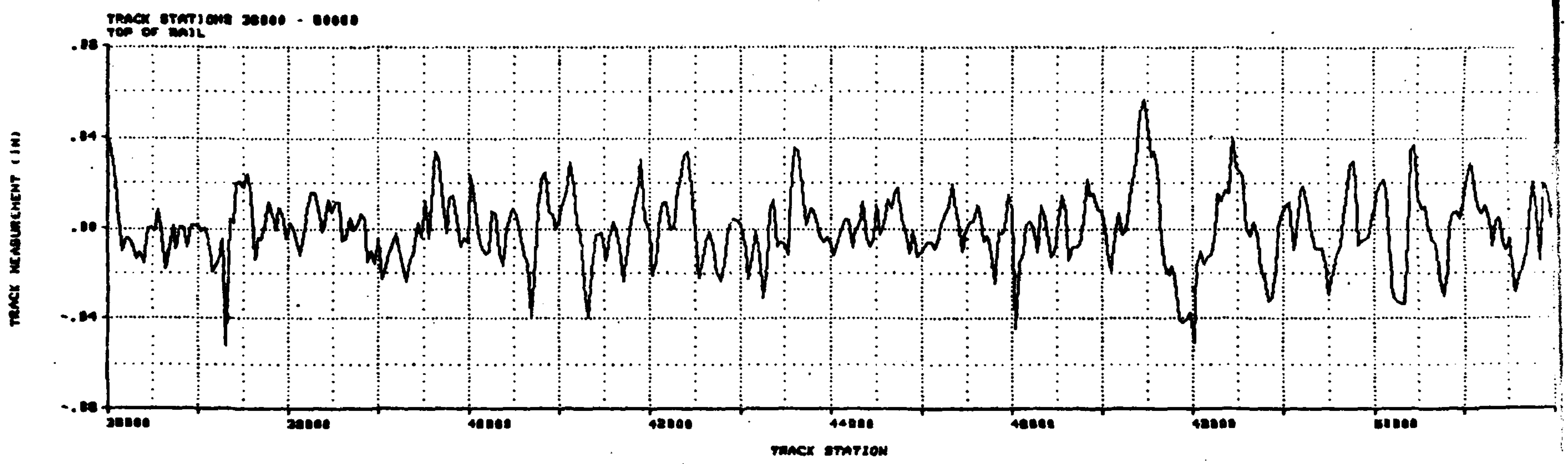
.04
.00
-.04
-.08
TRACK STATION
TRACK MEASUREMENT (IN)


TRACK STATIONS 36000 - 52000
TOP OF RAIL
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.04
.00
-.04
-.08
TRACK MEASUREMENT (IN)
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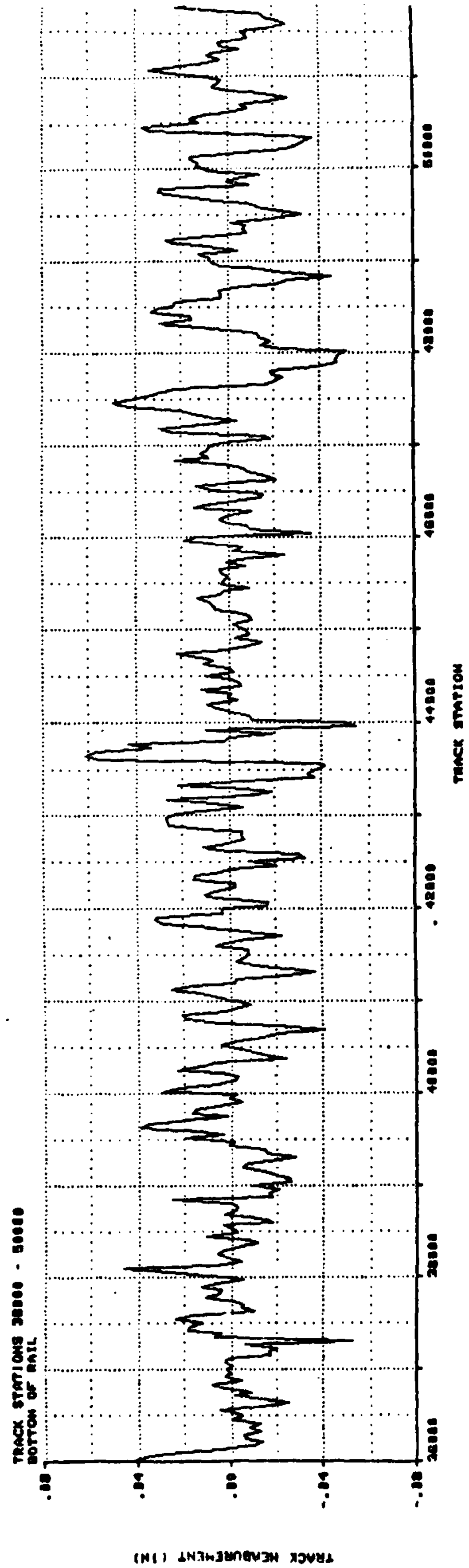
38000
40000
42000
44000
46000
48000
50000
TRACK STATION


TRACK STATIONS 36000 - 50000
BOTTOM OF RAIL
TRACK MEASUREMENT (IN)
TRACK STATION
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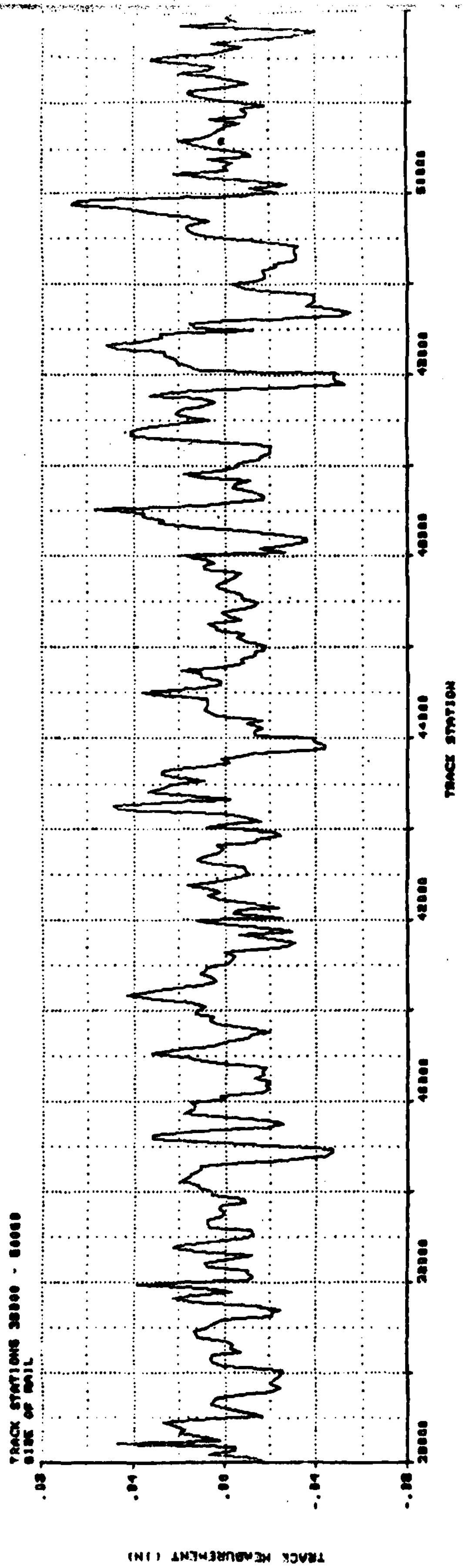
.04
.00
-.04
-.08
36000
38000
40000
42000
44000
46000
48000
50000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